WASTEFIELD TRANSPORT
STUDIES

Kcd 8/11/93
my

Ca

CH2M HILL

Engineers
Planners
Economists
Scientists

16 August 1993

PDX30702.DY.R1

Patricia N.N. Young
American Samoa Program Manager
Office of Pacific Islands and Native American Programs
U.S. Environmental Protection Agency
75 Hawthorne Street (E-4)
San Francisco, California 94105

Dear Pat:

Subject: Joint Cannery Outfall Dye Study: Final Report for the Non-Tradewind Season Dye Study and Study Plan for the Tradewind Season Dye Study

Enclosed are three copies of the final dye study report for the first (non-tradewind season) dye study. The dye study results confirm the expected and predicted diffuser performance and the initial dilution criteria on which the mixing zone was based. Compliance with water quality standards, for a particular level of diffuser performance, was based on predictions made using our wastefield transport model. Final confirmation of compliance with water quality standards throughout the harbor will be based on water quality monitoring results being conducted by ASEPA. The wastefield transport model predictions will be subject to verification, based on these monitoring results, after the second dye study is completed and monitoring data are available.

The original (non-tradewind season) dye study plan is attached as an addendum to the dye study report. **This letter serves to present revisions to the first (non-tradewind season) dye study plan for the second (tradewind season) dye study.** The proposed revisions are:

[1] The dilutions measured during the fist dye study were higher than anticipated. The plumes from the diffuser were very difficult to track more than about 200 meters from the diffuser. Therefore, only a few measurements of dilution at the mixing zone boundary were made. Most attempts to measure dye at the mixing zone boundary resulted in no detectable dye concentrations (corresponding to dilutions of > 25,000:1). The second dye study will concentrate on finding and measuring the plume at distances near the

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mixing zone boundary (we will still measure dye concentrations at the diffuser and throughout the mixing zone). We will inject dye at a higher initial concentration to aid in tracking the plume through the mixing zone.

[2] We propose to reschedule the study from late August/early September until late September/early October. This time is still within the tradewind season and will meet the seasonal objectives and the permit requirements.

[3] Additional minor modifications include: collection of background density (CTD) profiles before, during, and after the dye study will be done (DO will also be measured concurrently with temperature, salinity, and depth); more detailed wind data collection will be done during the dye study period; and, if feasible, better estimates of flow rates from the StarKist surge tank will be attempted.

All other elements of the original dye study plan remain as previously presented. Please review our original study plan and the proposed changes and provide any comments or questions prior to the second dye study. Responses to comments on the original dye study plan are incorporated into that plan as attached to the enclosed dye study report. A few comments were received after the original plan was approved. For your convenience and files we have provided a separate response to those comments. The additional responses are attached to this letter.

If you have any questions or comments please call me at your convenience. I have sent the same information to Sheila Wiegman of ASEPA.

Sincerely,

CH2M HILL

Steven L. Costa
Project Manager

enclosure: three copies of non-tradewind (February 1993) dye study report with original dye study plan as an addendum
attachment: response to John McConnaughey comments

cc: Norman Wei, StarKist Seafood Co.
James Cox, Van Camp Seafood Co.

MEMORANDUM CH2M HILL

TO: File

COPIES: Pat Young/USEPA
Sheila Wiegman/ASEPA
Norman Wei/StarKist Seafood
James Cox/Van Camp Seafood
David Wilson/CH2M HILL/SEA

FROM: Steve Costa/CH2M HILL/SFO

DATE: 16 August 1993

SUBJECT: Response to John McConnaughey Comments on the Joint Cannery Outfall Non-Tradewind Season Dye Study Plan

PROJECT: PDX30702.DY.R1

This memorandum provides responses to comments by John McConnaughey of the Department of Marine and Wildlife Resources, American Samoa Government, on the *Joint Cannery Outfall Dye Study Plan*. These comments were received after the response to comments on the draft study plan had been prepared and sent to USEPA and ASEPA and a formal response to these comments was not prepared prior to conducting the dye study. However, CH2M HILL reviewed and incorporated, where appropriate, Mr. McConnaughey's comments and concerns. A copy of the comments is attached to this memorandum.

Detection and decomposition of dye. The dye does not measurably degrade over the time scales involved in the dye study. The pre- and post-study calibration of the fluorometer include effects of dye decomposition and/or quenching over the time of the study.

Fate of organic materials. The dye is injected into the effluent stream at the plant. The dye will show the behavior and general characteristics of the plume. A measurable difference in the various components of the effluent would be detected in the profiles of dye concentrations. However, over the initial trajectory of the plume the any fine material is expected to remain associated with the plume. Also see the responses to the following comments for further discussion.

Fate of cannery effluent. The dye study is intended to demonstrate diffuser operation and overall plume behavior (i.e. dilution, trapping depth, size, and transport direction) within the mixing zone. The sediment monitoring, wastefield transport model, and reef survey studies, required by the Joint Cannery Outfall NPDES permits in addition to the dye study, are intended to monitor harbor wide and long term effects of the discharge.

Impacts of flocculent and organic material on DO and light penetration. The relocation of the outfall to deep water in the outer harbor, and the design of a multiport high rate diffuser, was done to keep the plume submerged, to increase dilution, and to decrease harborwide nutrient concentrations. The effluent plume is expected to trap (as verified by the results of the dye study) well below the surface. In addition the canneries are segregating high strength waste and disposing of it in a permitted ocean disposal area, thus reducing nutrient and BOD levels in the remaining effluent. High strength waste segregation and the relocation of the outfall are expected to eliminate impacts on light penetration and reduce BOD and nutrient concentrations to acceptable levels. The dye studies, water quality monitoring, model simulations, and eutrophication study are permit conditions imposed to determine if the anticipated results are as expected (results of the first dye study indicate the plume is behaving as anticipated).

Condition of the coral reefs. The overall conditions of the harbor waters are expected to improve because of high strength waste segregation and outfall relocation as described above. A coral reef survey study is being done as required by the Joint Cannery Outfall NPDES permits.

Residence time of cannery effluent. The dye study is designed to investigate the behavior of the plume within the mixing zone to determine if the diffuser location and design are having the anticipated effects on the discharge. The calculation of harbor wide concentrations and residence times will be done using the water quality monitoring data and the wastefield simulation model in separate studies.

Direction of plume movement. The dye study will determine the direction of plume movement, within the mixing zone, at the time the study is done. Dye studies will be done during both of the oceanographic seasons (tradewind and non-tradewind). Plume movement, in the vicinity of the diffuser, will therefore be described under the range of conditions expected in Pago Pago Harbor.

ATTACHMENT

**Memorandum from John McConnaughey
to Sheila Wiegman**

Dated 15 January 1993

**Comments on Joint Cannery Outfall
Dye Study Plan**
(2 pages)

DEPARTMENT OF MARINE & WILDLIFE RESOURCES

AMERICAN SAMOA GOVERNMENT
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A. P. LUTALI
Governor

TAUESE P. F. SUNIA
Lt. Governor

RAY TULAFONO
Director

PHILIP LANGFORD
Deputy Director

January 15, 1993

FROM: John McConnaughey
Fisheries Biologist

TO: Sheila Wiegman, ASEPA
Norman Wei, StarKist Samoa Inc
Jim Cox, VCS Samoa Packing Company

SUBJECT: Comments on Joint Cannery Outfall Dye Study Plan.

I have just reviewed the "Joint Cannery Outfall Dye Study Plan" which was forwarded to out department for comments.

I am not very familiar with the methodologies used to conduct such outfall plumb studies, so I will not comment on those technical issues. I do have two questions concerning methodology:

1) As the dye (Rhodamine WT) is biodegradable, how long after the dye is subjected to environment is it still detectable? Do the analytical techniques used include a correction factor to account for the decomposition of the dye over time?

2) We are mostly concerned with the fate of the organic materials present in the waste plume. Do the flocculent materials and organic solids in the waste plume behave the same as the aqueous portion of the plume? Will the dye accurately show the movements of these materials?

My major concern for this study is to document the fate of the cannery effluent plume. Does it stay resident in the outer harbor waters for a period of time, or is quickly flushed out of the harbor regions? Or worse, do currents carry it back into the inner harbor regions?

Pago Pago harbor suffers from serious pollution problems, and attempts to eliminate all sources of waste water entering the harbor need to be taken. The potential problems associated with cannery outfall waste is that it adds large amounts of flocculent material, and organic material to the waters in the harbor. This increases the biological oxygen demand on the system, reduces light for photosynthesis.

The coral reefs in the outer harbor area have been observed to be covered with a fine sediment materials at all times at depths greater than about 15 feet. Most corals appear dead, and very little new recruitment has been observed. Live corals in the inner harbor areas are virtually non-existent.

I feel that the main questions we would be interested in answering with this study are:

1) Resident time of the cannery waste plume.

2) Direction of movements.

I would like to discuss with you the details of the field sampling times and locations, and if possible to join you on a couple trips. Please call me any time so we can discuss this further.

cc: Ray Tulafono, Director DMWR
Peter Craig, Chief Biologist DMWR

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL RESEARCH LABORATORY - NARRAGANSETT
HATFIELD MARINE SCIENCE CENTER
NEWPORT, OREGON 97365

November 25, 1992

PACIFIC ECOSYSTEMS BRANCH
TELEPHONE: (503) 867-4040

MEMORANDUM

SUBJECT: Review of Draft Dye Study Plan for Tuna Cannery NPDES Permits

FROM: Walter E. Frick *Walter E. Frick*
Physical & Chemical Processes Team

TO: Janet Hashimoto *J 12/3/92*
Region IX

I have participated in two separate dye studies and know that Steve Costa is himself familiar with dye studies. Based on this experience and my readings of the draft dye study, I find the plan basically acceptable.

However, all parties should be aware of the limitations and pitfalls of dye study work. I think the study team should be able to locate and sample the plume in the nearfield, as described on page 7, though even this task can be difficult and time consuming. The method of then using drogues to follow the water parcel to make subsequent measurements is a fairly standard technique. Short of intensive and extensive monitoring throughout a large area, I do not know of a better way to track the plume.

Given, however, that the nearfield monitoring accurately depicts plume concentrations, most likely this measurement program will tend to overestimate the subsequent dilution achieved. I can think of three reasons to support this conclusion: 1) The depth of the water varies significantly in the vicinity of the diffuser. Because the water column in which the initial dye measurement is made will stretch as it moves into deeper water, the depth of the plume maximum will maintain its relative position, therefore sinking to a greater depth. Thus measurements at drogue depth will no longer represent the plume maximum. 2) The same effect may be accompanied by vertical current shear so that the location of the plume maximum will also be uncertain. 3) Internal wave motion might change the depth and location of the plume. Finally, if the drogue moves into shallower water there is always the danger of getting caught on the bottom.

Of course, attempts can be made to counteract this problem by taking excursions from the drogue location in the effort to find the local maximum. Since knowledge of what direction is perpendicular to the plume centerline will be uncertain, this technique will also suffer uncertainties. However, the existence and importance of the mixing zone makes other locations less relevant. My recommendation is that as much profiling be done along this boundary as possible, using the drogue crossover point as a guide for concentrating the measurement effort.

In addition to the dye study, I examined the Technical Memorandum "Site-specific Zone of Mixing Determination for the Joint Cannery Outfall Project, Pago Pago Harbor, American Samoa." Assuming the density profiles are representative of the conditions of concern, my own limited modeling resulted in initial similar dilution predictions. I have no knowledge about density gradients in tropical waters but do not find what is called a "stronger gradient" on page 12 very strong compared to gradients elsewhere in coastal and estuarine water. The conductivity and temperature measurement program proposed for the dye study should be used to help ameliorate this concern.

The modeling presented in the mixing zone determination study only establishes overall dilutions. It does not factor in the background concentration to establish effective dilution or concentrations based on the interaction of the discharge with existing polluted ambient water. The new EPA guidance on plume modeling "Dilution models for effluent discharges" (Baumgartner, Frick, Roberts, and Fox, 1992) makes such estimates possible. The water quality measurements for Pago Pago Harbor in recent years indicate that water quality standards are exceeded and are occasionally high enough so that, even when they are not exceeded, the presence of a source may cause exceedances near the mixing zone.

The dye program should also help establish whether flow patterns in Pago Pago Harbor are as anticipated in the dye study plan: inflow at the surface and outflow at depth. This is different from the pattern in many estuaries in which outflow generally occurs near the surface.

I hope that the contractor will address these concerns further in forthcoming analyses of the dye studies.

cc: David Young

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

4 NOV 1992

MEMORANDUM

SUBJECT: Request for Review of Draft Dye Study Plan for Tuna Cannery NPDES Permits

TO: Harvey Holm
Chief, Pacific Ecosystems Branch, ERL-N

FROM: Janet Hashimoto Janet Y. Hashimoto
Chief, Marine Protection Section

We have been asked by the Office of Pacific Islands and Native American Programs to review the enclosed draft Dye Study Plan for the joint tuna cannery outfall located in Pago Pago Harbor, American Samoa. The purpose of the proposed dye study is to collect the necessary data to provide direct evidence of plume behavior and to verify predictions of dilution and dispersion of the wastefield. We request your permission to have Walter Frick assist us in this review because of his expertise in the field.

Also enclosed for Walt's reference, is a copy of the "Supporting Documentation for the Joint Cannery Outfall Zone of Mixing Application." The deadline for response has been extended until November 23, 1992.

If you have any questions, please call me at 415/744-1156 or David Stuart at 415/744-1168.

cc: David Young
Walter Frick

Rcd 9/3/91

CH2M HILL Engineers Planners Economists Scientists

August 30, 1991

PDX30702.PA.MZ

Dyke Coleman, Chairman
American Samoa Environmental Quality Commission
American Samoa Government
Pago Pago, American Samoa 96799

Subject: Supporting Documentation for the Joint Cannery Outfall Zone of Mixing Application

Dear Mr. Coleman:

Enclosed is a Technical Memorandum "*SITE-SPECIFIC ZONE OF MIXING DETERMINATION FOR THE JOINT CANNERY OUTFALL PROJECT, PAGO PAGO HARBOR, AMERICAN SAMOA*" which is intended as an attachment to the application for a zone of mixing in Pago Pago Harbor for the proposed Joint Cannery Outfall. The application was sent to you on August 8, 1991.

The main points of the overall technical approach are given in the Feasibility Study referred to in the zone of mixing application. The Technical Memorandum extends this work to a specific location. During the course of outfall design there were changes in the exact location of the diffuser, the discharge depth, the exact diffuser port dimensions, and the discharge angle which required some minor recalculations and additional model simulations to complete the Technical Memorandum and to maintain consistency between all of the project documents. We submitted the main body of the application without this Technical memorandum attachment in order to facilitate rapid review of the project.

We have been coordinating the permitting activities for this project with Sheila Wiegman of your office. A short project description was attached to the application. Detailed engineering drawings of the outfall were prepared by Makai Ocean Engineering an are provided in the Draft Environmental Impact Assessment (DEIA) prepared for this project. Copies of the DEIA were sent to your office in early August.

Copies of the application for the zone of mixing and this Technical Memorandum have been forwarded to Norman Lovelace of the USEPA. If you or your staff need any additional information please call me at your convenience. If I am not at my desk you can leave a message on my voice mail at (415) 652-8149 extension 2251.

Sincerely,

CH2M HILL

Steven L Costa

Steven L. Costa
Project Manager
Enclosure
cc: Sheila Wiegman/ASEPA
Norman Lovelace/USEPA
Pat Young/USEPA
Norman Wei/StarKist Seafood
James Cox/Van Camp Seafood

TECHNICAL MEMORANDUM

CH2M HILL

TO: File

COPIES: Dyke Coleman/ASEQC
Sheila Wiegman/ASEPA
Norman Lovelace/USEPA
Pat Young/USEPA
Norman Wei/StarKist Seafood
James Cox/Van Camp Seafood

FROM: Steve Costa/CH2M HILL/SFO

DATE: August 26 1991

SUBJECT: SITE-SPECIFIC ZONE OF MIXING DETERMINATION FOR THE JOINT CANNERY OUTFALL PROJECT: PAGO PAGO HARBOR, AMERICAN SAMOA

PROJECT: PDX30702.PA.MZ

PURPOSE

StarKist Samoa and Samoa Packing Company discharge treated wastewater from tuna cannery operations into the inner part of Pago Pago Harbor. The canneries are proposing to replace the existing outfalls with a single, jointly operated, outfall extending into the outer portion of the harbor. However, a zone of mixing will be required since water quality standards can not be met at the point of discharge. The purpose of this memorandum is to provide technical documentation for the zone of mixing application for the joint cannery outfall.

The development of the technical approach and preliminary analyses were done for the *Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives* (CH2M HILL 1991) which will be referred to as the Feasibility Study below. This technical memorandum follows the methodology developed during the Feasibility Study and addresses additional information and model results for the discharge location and diffuser configuration selected during final design. **The dimensions and location of the zone of mixing are substantially the same as described in the Feasibility Study report.**

APPROACH AND SCOPE

The approach used in developing the final configuration of the zone of mixing includes the following elements:

[1] Review and summarize the effluent characteristics of both canneries and determine the anticipated range of variation of the characteristics of concern for defining the zone of mixing.

[2] Develop and recommended final diffuser configuration based on: the preliminary analysis done for the Feasibility Study, the effluent characteristics, and the location, depth, and other constraints imposed by the final outfall design. The final outfall design was conducted by Makai Ocean Engineering, Inc. The selection of final diffuser configuration was an iterative process involving predicted diffuser performance, engineering design considerations, and environmental criteria.

[3] Predict initial dilution of the final diffuser configuration for the range of effluent and receiving water conditions anticipated.

[4] Predict the ambient concentrations of total phosphorus (TP) and total nitrogen (TN) throughout the harbor based on TN and TP loadings of the cannery effluent.

[5] Use the effluent concentrations, the initial dilution predictions for the final design, and the predicted ambient concentrations to predict the required size and geometry of the zone of mixing.

A more complete description of the approach and the models used is provided in the Feasibility Study and the Appendices to the Feasibility Study. The scope of this technical memorandum involves an extension of the modeling, analysis, and predictions done for the Feasibility Study.

EFFLUENT CHARACTERISTICS

The effluent characteristics of primary concern in defining the dimensions of the zone of mixing are the effluent flow rates, effluent density, and the concentrations and loadings of TN and TP. The establishment of a zone of mixing for TN and TP will be sufficient to provide for other water quality characteristics such as temperature. The effluent characteristics used to develop the necessary zone of mixing geometry are based on the time period after high strength waste segregation was started (August 1990). The flow, concentration, and loading data used below are representative of times of product processing.

EFFLUENT DISCHARGE RATES

Discharge rates used in the zone of mixing analysis were based on flows recorded during the twice weekly sampling conducted by the canneries. The period of record for StarKist Samoa (SKS) was from August 8, 1990 through May 13, 1991, and for Samoa Packing Co.

(SPC) from August 6, 1990 through March 27, 1991. Cumulative frequency distributions were constructed for these records and are presented in Table 1. The median flows were 1.83 million gallons per day (mgd) for SKS and 0.56 mgd for SPC. The average flows for SKS and SPC, for the period of record, were 1.78 and 0.58 mgd, respectively. The anticipated future flow maximum for SKS and SPC combined is estimated to be 4.8 mgd.

Table 1
FREQUENCY DISTRIBUTION OF EFFLUENT DISCHARGE RATES

Cumulative Frequency: Percent of Time Flow is Equal to or Less Than Tabulated Value	Effluent Discharge Rate (mgd)	
	StarKist Samoa	Samoa Packing Co.
1	1.04	0.37
5	1.27	0.44
10	1.41	0.45
25	1.63	0.51
50	1.83	0.56
75	1.95	0.64
90	2.00	0.71
95	2.10	0.76
100	2.61	0.79

= 3.4

EFFLUENT DENSITY

The difference in density between the effluent and the receiving waters is an important parameter in determining the initial dilution and the trapping level of the effluent plume. The effluent density depends on the temperature and salinity of the effluent. The temperature range of the effluent from both canneries is limited to a few degrees and does not have a large effect on effluent density. This range is between 85 and 90 degrees F.

The salinity varies due to the use of sea water by SKS. The amount of sea water used has been approximately 60 percent of the total effluent stream. Approximately 0.6 mgd of seawater is used by SKS for thawing and the remainder has been used for cooling purposes. It is anticipated that about 0.6 mgd of sea water will be used by SKS in the future.

EFFLUENT TN AND TP LOADINGS

TN and TP loadings (pounds per day) and concentrations (mg/l) used in the zone of mixing analysis were based on samples analyzed for the twice weekly sampling conducted by the canneries. The period of record for SKS data was from August 8, 1990 through March 29, 1991 and includes 64 samples. The period of record available for SPC data was from August 6, 1990 through March 27, 1991 and includes 69 samples. Cumulative frequency distributions were constructed for both TN and TP loadings and are presented in Table 2.

The median loadings for TP were 127 lbs/day for SKS and 153 lbs/day for SPC. The average TP loadings for SKS and SPC, for the period of record, were 134 and 160 lbs/day, respectively. The anticipated future maximum TP loading for SKS and SPC combined is approximately 600 lbs/day.

Table 2
FREQUENCY DISTRIBUTION OF TN AND TP LOADINGS

Cumulative Frequency: Percent of Time Loading is Equal to or Less Than Tabulated Value	TP LOADINGS (lbs/day)		TN LOADINGS (lbs/day)	
	SKS	SPC	SKS	SPC
1	40	77	445	136
5	48	103	566	306
10	55	119	683	334
25	79	130	851	411
50	127	153	1020	477
75	171	188	1228	570
90	230	208	1427	673
95	257	225	1720	772
100	312	267	1925	1052

✓ ≈ 600

✓ 3500 - 4000

anticipated future max. loads
based on what flow? 4.8 or 3.4?

The median loadings for TN were 1020 lbs/day for SKS and 477 lbs/day for SPC. The average TN loadings for SKS and SPC, for the period of record, were 1061 and 506 lbs/day, respectively. The anticipated future maximum TN loading for SKS and SPC combined is approximately 3500 to 4000 lbs/day.

EFFLUENT TN AND TP CONCENTRATIONS

TN and TP concentrations used in the zone of mixing analysis were based on the same samples and periods of record as the loadings discussed above. Cumulative frequency distributions were constructed for both TN and TP concentrations and are presented in Table 3.

The median concentrations for TP were 8 mg/l for SKS and 34 mg/l for SPC. The average TP concentrations for SKS and SPC, for the period of record, were 9 and 33 mg/l, respectively.

The median concentrations for TN were 66 mg/l for SKS and 104 mg/l for SPC. The average TN concentrations for SKS and SPC, for the period of record, were 69 and 104 mg/l, respectively.

Table 3
FREQUENCY DISTRIBUTION OF TN AND TP CONCENTRATIONS

Cumulative Frequency: Percent of Time Concentration is Equal to or Less Than Tabulated Value	TP CONCENTRATION (mg/l)		TN CONCENTRATION (mg/l)	
	SKS	SPC	SKS	SPC
1	2	17	32	28
5	3	20	35	67
10	4	23	46	77
25	6	29	55	85
50	8	34	66	104
75	11	38	79	121
90	14	42	90	140
95	16	43	114	146
100	20	48	125	183

DIFFUSER CONFIGURATION

Preliminary diffuser configuration and performance for a range of potential conditions and locations were investigated for the Feasibility Study. The results of the Feasibility Study indicated a general location for the diffuser. The final design of the outfall fixed a more precise location and other parameters such as pipe size and water depth. The selection of a final diffuser configuration was based on desired performance, design criteria for the outfall, and location in the harbor.

The important elements of the diffuser configuration include: number of ports, port diameter, port spacing, and port orientation. Each of these parameters is first discussed below in general terms. More specific and detailed development of the selected configuration follows the general discussion.

GENERAL CONSIDERATIONS

Port orientation is important for a variety of reasons but is not considered in detail for this diffuser because: [1] port spacing is set to minimize individual plume merging, [2] current directions are not well known and diffuser configuration and initial dilution predictions were generally based on the zero current, worst case, assumption, and [3] the depth of the diffuser insures trapping well below the surface. General practice for best performance is to set the ports to discharge close to horizontally, sequentially alternating sides on the diffuser pipe, and to set them normal to the diffuser axis. This was the approach used for the port arrangement.

Closely spaced ports minimize diffuser length and thus materials and construction costs. However, closely spaced ports may result in merging of individual plumes and result in lower initial dilutions than would be achieved for larger port spacings. The procedure followed below was to fix port spacing to minimize merging.

Port size and number of ports effect initial dilution primarily by controlling effluent volume flow and velocity from each port. Higher velocities and lower volumes increase, in general, initial dilution. There are practical limits on size and numbers of ports including head loss, constructibility, and maintenance considerations. Based on experience with outfalls and diffusers, there are some general ground rules that can be applied for preliminary diffuser configuration development. These general guidelines include:

- Total port area should be between 1/3 and 2/3 of the area of the outfall pipe.

- Port velocities vary from 6 to 15 feet per second.

- Densimetric Froude Numbers are generally in the range of 15 to 30, with peaks no higher than 40 to 50.

- Port diameters are usually in the range of 3 to 9 inches.

The nominal diameter of the outfall pipe is 16 inches corresponding to a cross-sectional area of approximately 201 square inches. The number of ports of a given diameter should be in the range shown in Table 4 in the columns for minimum and maximum number of ports. Table 4 also indicates the port discharge velocities corresponding to the port diameters and numbers tabulated, for a representative range of total effluent flow rates. The data presented in Table 4 are interpreted as follows:

- The total flows of 0.37 and 1.41 mgd are the minimum flows for SPC (lowest single cannery flow) and for SPC plus SKS (lowest combined flow), respectively (see Table 1). This range of flows represents low flow conditions and the generally accepted criteria is that the Densimetric Froude Number associated with the flows should remain above 1 or 2. This will be discussed further below.

- The flow rate of 3.4 mgd is the combination of the maximum flow rates for both canneries. It represents a condition of very low probability under present operational practices at the canneries. This flow should be result in a Densimetric Froude Number of less than 40 to 50 (discussed further below) and should not result in velocities of over about 20 to 25 ft/sec through the ports. The latter condition is not a constraint as indicated in Table 4.

- The flow rate of 2.39 mgd is the combined median flows for both canneries. This value is taken as the design flow for the purposes of this discussion. The shaded portions of Table 4 highlight conditions where the velocity is between 6 and 15 ft/sec. The shaded entries indicate that the entire range of port sizes considered can accommodate the design flow rate and also meet the port-to-pipe area ratio criteria.

Table 4
PORT CONFIGURATION CHARACTERISTICS

PORT DIAMETER (inches)	PORT AREA (sq.in)	NUMBER OF PORTS (minimum)	TOTAL FLOW (mgd)	PORT VELOCITY (ft/sec)	NUMBER OF PORTS (maximum)	TOTAL FLOW (mgd)	PORT VELOCITY (ft/sec)
3	7.07	9	0.37	1.30	19	0.37	0.61
			1.41	4.94		1.41	2.34
			2.39	8.37		2.39	3.97
			3.40	11.91		3.40	5.64
4	12.57	5	0.37	1.31	11	0.37	0.60
			1.41	5.00		1.41	2.27
			2.39	8.48		2.39	3.85
			3.40	12.06		3.40	5.48
5	19.63	3	0.37	1.40	7	0.37	0.60
			1.41	5.33		1.41	2.29
			2.39	9.04		2.39	3.87
			3.40	12.86		3.40	5.51
6	28.27	2	0.37	1.46	5	0.37	0.58
			1.41	5.56		1.41	2.22
			2.39	9.42		2.39	3.77
			3.40	13.40		3.40	5.36
7	38.48	2	0.37	1.07	3	0.37	0.71
			1.41	4.08		1.41	2.72
			2.39	6.92		2.39	4.61
			3.40	9.84		3.40	6.56
8	50.27	1	0.37	1.64	3	0.37	0.55
			1.41	6.25		1.41	2.08
			2.39	10.59		2.39	3.53
			3.40	15.07		3.40	5.02
9	63.62	1	0.37	1.30	2	0.37	0.65
			1.41	4.94		1.41	2.47
			2.39	8.37		2.39	4.19
			3.40	11.91		3.40	5.95
10	78.54	1	0.37	1.05	2	0.37	0.52
			1.41	4.00		1.41	2.00
			2.39	6.78		2.39	3.39
			3.40	9.65		3.40	4.82
11	95.03	1	0.37	0.87	1	0.37	0.87
			1.41	3.31		1.41	3.31
			2.39	5.60		2.39	5.60
			3.40	7.97		3.40	7.97
12	113.10	1	0.37	0.73	1	0.37	0.73
			1.41	2.78		1.41	2.78
			2.39	4.71		2.39	4.71
			3.40	6.70		3.40	6.70

- Unusually large port areas (10 to 12 inches in diameter) are included in Table 4 for comparison purposes. These large ports would be less expensive to construct, result in lower operating costs because of lower head losses, and have lower potential maintenance problems.

Densimetric Froude Numbers are given in Table 5 for extremes in receiving water conditions and for the range of effluent flow rates and densities anticipated. Densimetric Froude Number depends on receiving water density, effluent density, port diameter, and port discharge velocity. The range of ambient densities is estimated to be between 1.0227 and 1.0234 grams per cubic centimeter. The range of effluent densities is estimated between 0.9550 and 1.0011 g/cc. For these conditions, and the range of port diameters used in Table 4,the velocities associated with Froude Numbers of 2, 15, 30, and 50 were calculated and presented in Table 5. The interpretations of the results given in Table 5 are as follows:

- In outfalls with large variations in flows there is the potential for sea water intrusion at flows well below design conditions. Froude Numbers should remain above 1 or 2 (or possibly higher) to avoid sea water recirculation in the outfall. Long periods of such conditions can lead to sediment accumulation in the outfall and biofouling of the diffuser ports. To avoid this problem the velocity given in Table 5 for Fr = 2 should be equal to or lower than the velocities given for the minimum flows of Table 4. Examination of these data indicates that the use of ports larger than 9 inches in diameter may lead to problems associated with sea water intrusion.

- Maximum flows should result in a Froude Number of less than about 40 to 50. Examination of the velocities predicted for Fr = 50 in Table 5 and conditions for maximum flow rates indicates that maximum anticipated flows through the appropriate number of ports will not exceed 30 and the maximum condition is not a problem in diffuser configuration design.

- The criteria that flows should result in Froude Numbers between 15 and 30 means that velocities given in Table 4 should be above the velocities for Fr = 15 in Table 5. This condition is met for port diameters between 3 and slightly less than 6 inches as indicated by the shaded areas of table 5. In all cases the number of ports would have to be less than the maximum number listed to meet the Fr => 15 criteria.

Table 5
PORT DYNAMICS CHARACTERISTICS
Fr = Densimetric Froude Number

g' (ft/s/s)	PORT DIAMETER (inches)	PORT VELOCITY (ft/sec)			
		Fr = 2	Fr = 15	Fr = 30	Fr = 50
0.89	3	0.94	7.08	14.17	23.61
	4	1.09	8.18	16.36	27.26
	5	1.22	9.14	18.29	30.48
	6	1.34	10.02	20.03	33.39
	7	1.44	10.82	21.64	36.07
	8	1.54	11.57	23.13	38.56
	9	1.64	12.27	24.54	40.90
	10	1.72	12.93	25.87	43.11
	11	1.81	13.56	27.13	45.21
	12	1.89	14.17	28.33	47.22
0.68	3	0.82	6.18	12.36	20.60
	4	0.95	7.14	14.27	23.79
	5	1.06	7.98	15.96	26.59
	6	1.17	8.74	17.48	29.13
	7	1.26	9.44	18.88	31.47
	8	1.35	10.09	20.18	33.64
	9	1.43	10.70	21.41	35.68
	10	1.50	11.28	22.57	37.61
	11	1.58	11.83	23.67	39.45
	12	1.65	12.36	24.72	41.20

Based on general criteria derived from experience with outfall systems as reported in the engineering literature, and the desire to use the largest ports possible, the 5 to 6-inch port configurations appear to be the most desirable. Smaller ports generally result in higher initial dilutions and thus would require a smaller zone of mixing. However, using larger ports is particularly important for this case since the diffuser will be in deep water (nearly 180 feet) and the cost associated with clogged or plugged ports could be substantial. To further assist in selecting a final diffuser configuration that balances these two conflicting objectives, sensitivity studies for initial dilution performance were done as described below.

DIFFUSER PERFORMANCE SENSITIVITY

The sensitivity of diffuser performance (initial dilution and trapping depth) to environmental parameters, effluent characteristics, and diffuser configuration was investigated to aid in final diffuser configuration selection. The model UDKHDEN, which is described in more detail in the Feasibility Study, was used for the sensitivity analysis. The models UDKHDEN and UMERGE were both used for the Feasibility Study. However, UDKHDEN is considered more sensitive to changes in receiving water and effluent characteristics and was the only model used for developing the sensitivity analysis presented here.

The sensitivity analysis considers two receiving water conditions: a stronger density gradient representative of trade wind conditions and a weaker density gradient representative of non-trade wind conditions. These density gradients were developed from available data from stations close to the proposed diffuser location. The density gradients used are given in Table 6.

The analysis presented below generally considers a discharge depth of 160 feet, port sizes of between 4 to 8 inches, number of ports equivalent to about one-half the area of the outfall pipe, and effluent densities consistent with approximately 40 percent sea water. More detailed considerations of some of these factors is considered in the subsequent development of the final diffuser configuration presented after the initial sensitivity analysis.

Sensitivity to Port Spacing

Table 7 summarizes model predictions showing the sensitivity of diffuser performance to port spacing. A port spacing of 50 feet results in merging plumes at the trapping level for the stronger stratification conditions. Under weaker stratification the plumes

Table 6
RECEIVING WATER DENSITY PROFILES USED FOR DIFFUSER CONFIGURATION SENSITIVITY ANALYSIS

DEPTH (meters)	DENSITY (sigma-t units)	
	STRONGER GRADIENT	WEAKER GRADIENT
0	23.02	22.65
3	23.02	22.65
6	23.13	22.68
9	23.13	22.68
12	23.20	22.68
15	23.28	22.68
18	23.28	22.68
21	23.28	22.68
24	23.36	22.68
27	23.36	22.68
30	23.36	22.68
33	23.36	22.68
36	23.36	22.68
39	23.36	22.68
41	23.36	22.68
44	23.36	22.68
47	23.36	22.69
49	23.43	22.71
55	23.43	22.71

merge prior to trapping but higher initial dilutions also result since the trapping level is higher in the water column. A port spacing of approximately 50 feet was chosen as resulting in the best overall performance of the diffuser configuration. Table 7 also indicates the better performance of smaller ports.

Table 7

EFFECT OF PORT SPACING ON INITIAL DILUTION

Discharge Depth	= 160 ft
Effluent Flow Rate	= 2.0 mgd
Effluent Temperature	= 85 F
Current Velocity	= 0 cm/sec

Results for Port Spacing = 25ft						
PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	366	72.5 (22.1)	36 (11)	YES
4	7	W	590	12.0 (3.5)	46 (14)	YES
6	4	S	260	69.6 (21.2)	36 (11)	YES
6	4	W	432	surface	50 (15.3)	YES
8	2	S	205	45.0 (13.7)	44 (13.5)	YES
8	2	W	277	surface	47 (14.4)	YES

Results for Port Spacing = 50ft						
PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	471	73.8 (22.5)	44 (13.5)	YES
4	7	W	903	14.4 (4.4)	61 (18.5)	YES
6	4	S	334	71.9 (21.9)	46 (14)	YES
6	4	W	636	11.5 (3.5)	62 (19)	YES
8	2	S	291	47.9 (14.6)	57 (17.5)	YES
8	2	W	439	surface	64 (19.6)	YES

Note: S=strong density gradient W=weak density gradient

Sensitivity to Effluent Flow Rate

A representative range of effluent flow rates is presented in Table 8 for both density gradient conditions and a range of port sizes. Port Spacing is held at 50 feet. At the higher flow rates initial dilution decreases and plume trapping level is shallower. At the highest discharge rates the plume surfaces at port diameters of greater than six inches for the weaker density gradient condition.

Sensitivity to Effluent Temperature

Table 9 shows the sensitivity of diffuser performance to effluent temperature (an thus to effluent density). The results indicate that the initial dilution and trapping level are insensitive to small changes in effluent temperature (or density) for the range of port sizes under consideration at an effluent flow rate and depth similar to the expected conditions for the joint cannery outfall.

Sensitivity to Ambient Currents

All of the diffuser performance predictions presented above were based on a worst case scenario of zero ambient current. This is a conservative approach. Existing data (described in the Feasibility Study) indicates that a small current will be present nearly continuously at the diffuser site. Table 10 presents the diffuser performance predictions for currents at about the estimated 10 percentile level of 5 cm/sec (currents will be higher than this 90 percent of the time). Comparison of the results given in Table 10 to the zero current results of Table 8 demonstrates that, as expected, the presence of currents dramatically increases the initial dilution and trapping levels for the range of port sizes and effluent flows representative of the joint cannery outfall conditions.

SELECTION OF DIFFUSER CONFIGURATION

Based on the general guidelines for diffuser design, the results of the sensitivity analysis, and consideration of other design and site-specific factors, ports of 5-inch diameter were selected. During the time the sensitivity study was being conducted the exact location of the diffuser was selected and the depth at that location is 171 to 176 feet relative to mean lower low water.

The number of ports for the final diffuser configuration was based on the results of a series of model predictions for 5-inch ports as given in Table 11. Table 11 provides the predicted trapping

Table 8

EFFECT OF EFFLUENT FLOW RATE ON INITIAL DILUTION

Discharge Depth	= 160 ft.
Port Spacing	= 50 ft.
Effluent Temperature	= 85 F
Current Velocity	= 0 cm/sec

Results for Minimum Effluent Flow Rate = 1.5 mgd

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	540	75 (22.8)	43 (13.0)	YES
4	7	W	1068	15 (4.6)	61 (18.5)	YES
6	4	S	380	73 (22.2)	43 (13.2)	YES
6	4	W	743	13 (4.1)	62 (18.8)	YES

Results for Average Effluent Flow Rate = 2.0 mgd

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	471	73.8 (22.5)	44 (13.5)	YES
4	7	W	903	14.4 (4.4)	61 (18.5)	YES
6	4	S	334	71.9 (21.9)	46 (14)	YES
6	4	W	636	11.5 (3.5)	62 (19)	YES
8	2	S	291	47.9 (14.6)	57 (17.5)	YES
8	2	W	439	surface	64 (19.6)	YES

Results for Maximum Effluent Flow Rate = 3.8 mgd

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	357	73 (22.1)	49 (14.8)	YES
4	7	W	629	12 (3.6)	64 (19.6)	YES
6	4	S	256	69 (21.1)	50 (15.2)	YES
6	4	W	465	surface	67 (20.3)	YES

Note: S=strong density gradient W=weak density gradient

Table 9

EFFECT OF TEMPERATURE ON INITIAL DILUTION

Discharge Depth = 160 ft.
Effluent Flow Rate = 2.0 mgd
Port Spacing = 50 ft.

Results for Ambient Current = 0 cm/sec

PORT SIZE (inches)	PORT NUMBER	EFFLUENT TEMP. (F)	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	85	S	468	74 (22.5)	44 (13.5)	YES
4	7	90	S	478	73 (22.4)	44 (13.4)	YES
4	7	85	W	900	14 (4.3)	62 (18.8)	YES
4	7	90	W	915	14 (4.4)	61 (18.7)	YES
6	4	85	S	332	72 (21.9)	43 (13.0)	YES
6	4	90	S	339	72 (21.8)	44 (13.5)	YES
6	4	85	W	630	11 (3.5)	62 (19.0)	YES
6	4	90	W	644	11 (3.3)	62 (19.0)	YES

Results for Ambient Current = 5.0 cm/sec (Currents higher than this 90% of time)

PORT SIZE (inches)	PORT NUMBER	EFFLUENT TEMP. (F)	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	85	S	2507	78 (23.8)	69 (21)	YES
4	7	90	S	2511	78 (23.7)	69 (21)	YES
4	7	85	W	4651	19 (5.8)	108 (33)	YES
4	7	90	W	4659	19 (5.8)	112 (34)	YES
6	4	85	S	1471	77 (23.6)	82 (25)	YES
6	4	90	S	1472	77 (23.6)	82 (25)	YES
6	4	85	W	2725	18 (5.6)	128 (39)	YES
6	4	90	W	2730	18 (5.5)	131 (40)	YES

Note: S=strong density gradient W=weak density gradient

Table 10

EFFECT OF AMBIENT CURRENT AND EFFLUENT FLOW RATE ON INITIAL DILUTION

Discharge Depth = 160 ft.
Port Spacing = 50 ft.
Effluent Temperature = 85 F

Results for Minimum Effluent Flow Rate = 1.5 mgd

Current Velocity = 5 cm/sec

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	3244	78 (23.8)	66 (20)	YES
4	7	W	6079	19 (5.9)	102 (31)	YES
6	4	S	1902	77 (23.6)	79 (24)	YES
6	4	W	3552	18 (5.7)	200 (61)	YES

Results for Average Flow Rate = 2.0 mgd

Current Velocity = 2.5 cm/sec

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	1414	77 (23.6)	118 (36)	YES
4	7	W	2588	18 (5.5)	157 (48)	YES
6	4	S	854	76 (23.3)	85 (26)	YES
6	4	W	1557	17 (5.1)	125 (38)	YES
8	2	S	487	73 (22.4)	79 (24)	YES
8	2	W	866	14 (4.2)	131 (40)	YES

Current Velocity = 5.0 cm/sec

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	2509	78 (23.8)	69 (21)	YES
4	7	W	1472	77 (23.6)	82 (25)	YES
6	4	S	4655	19 (5.8)	110 (34)	YES
6	4	W	2728	18 (5.6)	129 (40)	YES

Results for Maximum Flow Rate = 3.8 mgd

Current Velocity = 5 cm/sec

PORT SIZE (inches)	PORT NUMBER	DENSITY PROFILE	DILUTION	TRAPPING LEVEL – ft (m)	PLUME WIDTH AT TRAP. LEVEL	PLUMES MERGE
4	7	S	1440	77 (23.6)	72 (22)	YES
4	7	W	2600	18 (5.6)	121 (37)	YES
6	4	S	857	76 (23.3)	85 (26)	YES
6	4	W	1536	17 (5.2)	144 (44)	YES

Note: S=strong density gradient W=weak density gradient

level, initial dilution, and Froude Number for a range of effluent flow rates and for both density gradient conditions described above. Effluent density was based on 40 percent sea water and a temperature of 87.5 degrees F. The results of these model predictions lead to the selection of a diffuser with the following characteristics:

- Number of Ports: 6 ports total
  4 ports active (open)
  2 ports closed (for future use)

- Port Spacing: 50 feet between ports
  Alternating sides

- Port Size: 5.065 inches (ID)

- Port Orientation: 90 degrees to centerline of pipe
  15 degrees to horizontal (upward)

The number of ports to be built is larger than the number of ports to be used. This provides flexibility for growth and a safety factor in the event of port clogging. This approach was taken because of the depth of water and difficulty of modifying and maintaining the diffuser once in place.

PREDICTED DIFFUSER PERFORMANCE

After determining the final diffuser configuration described above and the location (depth) of the diffuser an additional set of model simulations was conducted to predict final diffuser configuration performance. The results of these predictions are given in Table 12 and detailed input and output from UDKHDEN are provided in the Appendix A to this memorandum. For the final configuration model predictions the following conditions were used:

- Effluent Discharge Rates: 1.41, 2.39, and 3.40

- Effluent Temperature: 85 degrees F

- Effluent Salinity: Calculated for 0.6 mgd of sea water (the balance freshwater)

- Ambient Conditions: Density as described above and zero current speed

Table 11
SELECTION OF NUMBER OF 5-inch PORTS FOR DIFFUSER

DENSITY GRADIENT S=strong W=weak	EFFLUENT FLOW (mgd)	NUMBER OF 5-inch PORTS	TRAPPING LEVEL (m below surface)	INITIAL DILUTION	FROUDE NUMBER
S	1.5	2	22	350	4.4
		4	23	491	5.8
		6	23	611	8.7
		8	23	707	17.5
	2.0	2	22	310	23.2
		4	23	428	11.6
		6	23	524	7.7
		8	23	608	5.8
	3.8	2	22	237	44.6
		4	22	312	22.3
		6	23	378	14.9
		8	23	433	11.2
W	1.5	2	4	565	17.8
		4	4	832	8.9
		6	5	1053	6.0
		8	5	1248	4.5
	2.0	2	3	487	23.6
		4	4	707	11.81
		6	4	896	7.87
		8	5	1059	5.91
	3.8	2	0	367	45.5
		4	3	498	22.8
		6	4	616	15.2
		8	4	721	11.4

Table 12
PREDICTED PERFORMANCE OF FINAL DIFFUSER CONFIGURATION

DENSITY GRADIENT	EFFLUENT FLOW (mgd)	TRAPPING LEVEL (m below surface)	INITIAL DILUTION
Stronger Gradient	1.41	23	467
	2.39	22	393
	3.40	21	346
Weaker Gradient	1.41	4	817
	2.39	3	659
	3.40	-	586

The model predictions indicate that dilutions are expected to be over 300:1 under all conditions and are over 400:1 under most conditions.

AMBIENT CONCENTRATIONS (OUTSIDE ZONE OF MIXING)

Ambient concentrations for a range of nutrient loadings and discharge locations were developed and presented in the Feasibility Study and Appendices to the Feasibility Study. These predictions were done using a wastefield transport model (PT121) developed for Pago Pago Harbor. The model is described in the Feasibility Study. Additional runs with the model were made for the final diffuser location.

Table 13 presents the results of the PT121 model runs for the final diffuser site. The loadings listed in Table 13 are input to the model as constants and can be interpreted to represent the maximum loading or the long term average loading. The interpretation of the results depends on the interpretation of the input loading conditions. The primary results of the site-specific model predictions are:

- **Interpretation of the model input as the maximum loading is the most conservative approach.** In this case the model predicts the resulting concentrations throughout the harbor that would occur if the maximum loadings were continuous (that is maximum and average were the same).

Since the loadings vary considerably (see Tables 2 and 3 and Figures in Appendix B of this memorandum), the predicted concentrations based on maximum loadings are values that are higher than would ever occur. The combined average loading of TP is only 49 percent of the combined maximum loading. For TN the combined average is only 50 percent of the combined maximum. The use of the maximum as an average is extremely conservative.

- **Interpretation of the model input loadings as averages means that the predicted concentrations in the harbor are representative of long term averages.** The actual concentrations in the harbor would fluctuate about these averages. Because of the slow response time of the harbor and the rapid variations of the loadings the actual concentrations in the harbor would not vary as much as the loadings. Concentrations in the harbor would never reach a value near that predicted for maximum loadings input as constant. For example, if the combined average TN loading is 1500 pounds per day and the maximum value is 4000 pounds per day then, based on the results given in Table 13, the average concentration in the harbor (highest value outside the mixing zone) is predicted to be higher than 0.165 mg/l and will always be lower than 0.243 mg/l.

- **Present combined average loadings are approximately 1500 lbs/day (1567 lbs/day for the samples taken during the period of record described above). This loading will result in a predicted maximum TN concentration outside of the zone of mixing of 0.165 mg/l.** This is comfortably below the water quality standard. For TP the loading is about 300 lbs/day (294 lbs/day for the period of record). This loading results in a maximum TP concentration, outside the zone of mixing, of about 0.022 mg/l.

- **The model predictions indicate that, outside the zone of mixing, the TN standard of 0.200 mg/l will be met at a constant loading of 2600 lbs/day and that the TP standard of 0.030 mg/l will be met at a constant loading of 570 lbs/day.** The 2600 lbs/day TN level includes 95 to 99+ percent of the data since the implementation of high strength waste segregation. The 570 lbs/day TP level includes virtually all the data since the implementation of high strength waste segregation.

Table 13
MODEL PREDICTIONS OF MAXIMUM CONCENTRATIONS OUTSIDE THE ZONE OF MIXING AT THE FINAL DIFFUSER SITE FOR A RANGE OF TN AND TP LOADINGS

TN LOADING (lbs/day)	MAXIMUM TN CONCENTRATION (mg/l)		TP LOADING (lbs/day)	MAXIMUM TP CONCENTRATION (mg/l)
1500	0.165		300	0.022
2000	0.180		400	0.025
2500	0.197		500	0.028
3000	0.212		600	0.031
3500	0.231		700	0.034
4000	0.243		800	0.038

Examination of the data for concentrations, loadings, and effluent flow rates, since high strength waste segregation, indicates that there is no significant trend of loading with production. Plots of concentration and loading as a function of relative production (percent of maximum in the period of record) are given in Appendix B. The time series of loadings for each cannery, since the implementation of high strength waste segregation, are also given in Appendix B and indicate that there is no strong correlation between canneries and that the fluctuations are of relatively short period. The variations in loading can be considered as a random record of short period fluctuations about a mean in the evaluation of impacts on harbor nutrient concentrations. ?

recovery time?

Based on the above observations the model was used to evaluate the increase in TN and TP concentrations that would occur for increases in loadings above a range of values for the combined long term average. The results of this analysis are given in Table 14. The table presents the number of days required to increase maximum TN and TP concentrations to the standard (outside of the zone of mixing). For example, if the average TN loading is 1500 lbs/day then an increased TN loading of 3000 lbs/day would have to exist for 7 consecutive days to increase the concentration of TN to 0.200 mg/l. This 0.200 mg/l concentration would be the highest concentration outside the zone of mixing; concentrations throughout the rest of the harbor would be lower than 0.200 mg/l.

The loadings used in the model simulation are based on data taken only during product processing operations and result in artificially high average loading values. These results in an extra degree of conservatism in an already conservative approach. All the model assumptions and applications tend to predict higher concentrations than would be the case with more realistic assumptions.

Table 14
MODEL PREDICTIONS OF MAXIMUM CONCENTRATIONS
FOR TN AND TP LOADINGS ELEVATED ABOVE AVERAGE

AVERAGE TN LOADING (lbs/day)	ELEVATED LOADING (lbs/day) 3000	3500	4000		AVERAGE TP LOADING (lbs/day)	ELEVATED LOADING (lbs/day) 600	700	800
	NUMBER OF DAYS BEFORE EXCEEDING 0.200 mg/l					NUMBER OF DAYS BEFORE EXCEEDING 0.030 mg/l		
1500	10	7	4		300	12	6	4
2000	7	4	3		400	9	4	3
2500	0	0	0		500	4	2	1

Examination of the available data indicates that TN loadings exceeding the average (1500 lbs/day) are not predicted to result in concentrations exceeding 0.200 mg/l. The average and maximum effluent TN and TP concentrations can increase above present values, to account for future growth, and still meet water quality standards. Table 14 indicates the average and maximum loadings predicted to result in compliance outside the zone of mixing.

by how much?

REQUIRED ZONE OF MIXING SIZE

The wastefield transport model described in the preceding section of this memorandum provides an assessment of the average concentrations throughout the harbor over time scales greater than a tidal period and space scales consistent with the cell size (200 meters horizontal dimension). The initial dilution model described above provides an assessment of the mixing action of the effluent plume with the receiving water. Neither of these models provides precise details on the geometry of a zone of mixing. For the purposes of the discussion in this section, the defined a zone of mixing is that area outside of which the water quality standards are achieved.

random

The enclosed nature of the harbor and concomitant long flushing and residence times, the stochastic nature of the predominantly wind-driven circulation, and the restrictive water quality standards all combine to make the precise definition of a zone of mixing a somewhat subjective process. However, the results of the wastefield transport model predictions show compliance with the water quality standards at specified loadings on a long-term average basis.

A number of approaches can be used to describe the appropriate zone of mixing dimensions. These approaches vary in their spatial and temporal resolution as well as in the physical approach used. The approaches can be broadly classified as initial dilution based, volumetric based, or based on analysis of subsequent (far-field) dilution. Each of these approaches is discussed below.

ZONE OF MIXING BASED ON INITIAL DILUTION

If a zone of mixing is to be based on initial dilution only, the receiving water must have a sufficiently low concentration of the constituent of concern that the concentration of the plume, at the end of the initial dilution process, meets the water quality standards. In an enclosed system like Pago Pago Harbor, the receiving water concentration (steady state or long term average) is elevated above the open ocean background concentration. Background concentration is used here to indicate the concentration that would be found if there were no release of the constituent. The steady-state concentration refers to the concentration in any particular area of the harbor that results from the long-term release of the constituent.

The required initial dilution (S) to meet a particular water quality standard concentration at the end of the initial dilution process (Cs) depends on the effluent concentration (Ce) and the ambient (steady state) concentration (Ca). The relationship between these variables is:

$$S \ (Ca - Cs) = (\overset{Ca\ *}{\cancel{Cs}} - Ce).$$

Thus, the standard can never be met if the ambient concentration equals the water quality standard and only initial dilution is accounted for in the zone of mixing definition.

The closer the values of the standard and the ambient concentrations, the more difficult it is to meet the standards, that is, the higher the initial dilution must be to meet the water quality

* As per Steve Costa's memo of 11/10/91

standard. For example, if the ambient TN concentration is the ocean background (the outfall is beyond the harbor entrance) of 0.12 mg/l and the water quality standard is 0.200 mg/l, the required initial dilution to meet the standard, except within the effluent plume, is expressed as:

$$S = (Ce - \overset{0.120*}{\cancel{0.200}})/0.080$$

Typical post-segregation median effluent concentrations for the combined cannery discharges are expected to be approximately 70 to 100 mg/l. This means that initial dilutions on the order of 875 to 1,250 are required, which are probably much higher than can practically be obtained. With the discharge in the harbor where the ambient concentrations are higher results in even higher, and unattainable, initial dilution requirements. A zone of mixing based solely on initial dilution is not feasible for the present water quality standards.

ZONE OF MIXING BASED ON VOLUMETRIC ANALYSIS

The transport model used to predict ambient conditions provides an assessment of the size of the zone of mixing, based on a description of long-term average concentrations. The resolution of the model is a cell 200 meters square (656 feet square). In addition, the model is a depth-averaged, completely stirred model. The fine-scale details of the effluent plume and the nearfield concentrations are neither square nor constant with depth or the horizontal dimension of a model cell. However, the model does give a good indication of the strength of the concentration gradient that can exist for the dispersion coefficient applicable for the model cell size.

The model was run with discharge to two cells. The resulting ambient concentrations given in Table 13 are the maximum predicted outside of those two cells. The time required to exceed the standard as given in Table 14 also is for areas outside of the two cells where effluent is discharged. For the discharge location the depth of the diffuser is about 175 feet and the minimum initial dilution expected from the initial dilution modeling is over 350:1. For an effluent concentration of TN of 100 mg/l, the concentration at the end of the initial dilution process is about 0.49 mg/l, based on an ambient concentration of 0.200 mg/l. The volume of water in 2 model cells is over 150 times that involved in the initial dilution process, and the concentration after initial dilution is approximately 2 to 3 times the average predicted for the 2 model cells.

The overall volumetric requirements for a zone of mixing predicted by the wastefield transport model appear reasonable (there is suf-

* As per S. Costa's memo of 11/10/91

ficient volume of water). However, the detailed geometry and spatial variability of the area where water quality standards are exceeded is not well addressed by the wastefield transport model (which predicts average long term conditions).

The wastefield transport model used in this study does provide a useful estimate of the subsequent dilution except close to the discharge point. The wastefield transport model (PT121) was found to predict observed concentrations at stations near (within 1000 feet of) the existing discharge. Thus, the results of the model near the point source discharge appear to be acceptable at a distance of about 1,000 feet or possibly less. The analysis of the wastefield transport model predictions presented in the previous section of this memorandum was based on providing a zone where water quality standards might be exceeded that was always less than 300 feet from the model discharge point.

If, as a conservative approach, the cells within which effluent is released and all the surrounding cells are taken as a zone of mixing the size of the zone of mixing would be 800 by 600 meters (approximately 2600 by 2000 feet) aligned in the direction of the diffuser.

APPLICATION OF THE FARFIELD DILUTION MODEL

The wastefield transport model described above is a depth-averaged model that cannot account for the fact that, near the discharge point, the wastefield will exhibit a gradient in concentration with depth and might be contained in a distinct layer of the water column. To investigate the expected concentrations near the discharge point the subsequent dilution model CDIFF was used.

The subsequent dilution model (CDIFF) was used and is described in more detail in the Feasibility Study and associated references. This model has features that make it conservative; that is, it provides predictions of dilutions that are probably low (high concentrations). These features include the following:

- The model allows no diffusion in the direction of the current. This results in particularly wide wastefields at low current speeds and physically unrealistic results at very low current speeds. This aspect of the model had to be considered for this application and was addressed as described below.

- The model allows no mixing in the vertical direction and assumes a constant "layer thickness". This results in an overestimate of concentrations.

- The model, as supplied by EPA, has set values for calculating diffusion coefficients as a function of plume dimension. These values result in a diffusion coefficient, at the start of subsequent dilution, that is about the same as that derived from dye experiments in Pago Pago Harbor. Those experiments were based on visual (photographic) observation rather than concentration measurements. This leads to an underestimate of the eddy diffusion coefficient and means CDIFF is underestimating the dilution factor (overestimating concentration) at least near the beginning of the subsequent dilution process.

- At the end of initial dilution, the concentration of the plume is appropriately described by adding or superimposing it on the ambient concentration. At the end of the subsequent dilution process, the concentration of the plume is the ambient concentration. However, the calculation of subsequent dilution is usually carried out by superimposing the plume concentration on the ambient concentration throughout the entire area considered. This gives conservative (concentration predicted too high) results that are more conservative as the distance from the source increases.

As mentioned above CDIFF does not work well under near-zero current conditions. The model allows only advective transport in the longitudinal direction (direction of current) and only diffusive transport in the lateral direction. Thus, for near zero current speeds no dispersion is allowed in the longitudinal direction and the model results are physically unrealistic, and are not usable for predictions. To be physically realistic, the longitudinal (advective) transport term should be at least as large as the lateral (diffusive) transport term. In order to meet this condition and keep model predictions physically realistic the model should not be applied for currents less than about 0.05 cm/sec. This current speed is based on an analysis done for the application of the model to Pago Pago Harbor.

For a current speed of 0.05 cm/sec and for diffusivity proportional to the length scale of the plume (which is typical for enclosed bodies of water), the model simulates the zero-current-speed situation. Under the stated current speed and diffusivity conditions the model predicts diffusive and advective fluxes of about the same size near the origin. This is equivalent to setting the strength of diffusive transport the same in both directions, which is a physically realistic approach for the space and time scales under consideration in this case.

The model output for CDIFF provides a description of subsequent dilution as a function of distance from the plume location at the end of initial dilution. The output from CDIFF is included as Appendix C. For the Feasibility Study the subsequent dilution was applied to the predicted gradient of ambient concentrations. For the analysis below the ambient concentrations are held constant, which is a somewhat more conservative approach. Tables 15A through 15D summarize the calculations and approach to predicting the required mixing zone dimensions.

Tables 15A-D summarize two approaches, which are similar to the approaches described above for the wastefield transport model:

- The first approach assumes a continuous loading for a range of values corresponding to a range of frequency of occurrences. This approach can be thought of as predicting the median (50 percentile) conditions for existing and increased (over 50% percentile) median loadings and concentrations.

- The second approach assumes a peak loading occurs superimposed on ambient conditions representative of the present median condition. An estimate of the number of days of elevated loadings that would have to occur before water quality standards were violated at the edge of the mixing zone was provided above in the discussion of the ambient concentrations predicted by the wastefield transport model.

There is no clear relationship between loading, concentration, and effluent discharge rate. The values used in the calculations were all selected corresponding to the same frequency of occurrence level. If the variables were well correlated this frequency would correspond to the expected frequency of occurrence of the result (i.e. required zone of mixing size). If the variables were not correlated at all then the frequency of the result could be much lower than the frequency of each variable. Since the relationship between the variables is weak, the result is conservative (predicted requirement for zone of mixing dimension is too large).

Tables 15A-D provide estimates of mixing zone size for TP and TN and for stronger and weaker density gradients. The tables are constructed as follows:

- Effluent flows, nutrient concentrations, and nutrient loadings are tabulated based on a set of frequencies from Tables 1 through 3 above.

Table 15A
REQUIRED DIAMETER FOR ZONE OF MIXING
TN – STRONGER STRATIFICATION

	CONTINUOUS CONDITIONS				PEAK SUPERIMPOSED ON MEDIAN			
FREQUENCY (Percent of Time Less Than or Equal to)	50%	75%	90%	95%	75%	90%	95%	100%
FLOW (mgd)								
SKS	1.83	1.95	2.00	2.10	1.95	2.00	2.10	2.61
SPC	0.56	0.64	0.71	0.76	0.64	0.71	0.76	0.79
COMBINED	2.39	2.59	2.71	2.86	2.59	2.71	2.86	3.40
CONCENTRATION (mg/l)								
SKS	66.00	79.00	90.00	114.00	79.00	90.00	114.00	125.00
SPC	104.00	121.00	140.00	146.00	121.00	140.00	146.00	183.00
COMBINED	74.90	89.38	103.10	122.50	89.38	103.10	122.50	138.48
LOADING (lbs/day, calc)								
SKS	1008	1286	1502	1998	1286	1502	1998	2723
SPC	486	646	830	926	646	830	926	1206
COMBINED	1494	1932	2332	2924	1932	2332	2924	3929
LOADING (lbs/day, data)								
SKS	1020	1228	1427	1720	1228	1427	1720	1925
SPC	477	570	673	772	570	673	772	1052
COMBINED	1497	1798	2100	2492	1798	2100	2492	2977
AMBIENT CONC. (mg/l)	0.165	0.174	0.183	0.197	0.165	0.165	0.165	0.165
STANDARD (mg/l)	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
REQUIRED DILUTION								
TOTAL DILUTION	2134	3430	6053	40768	2548	2940	3494	3951
INITIAL DILUTION	395	380	375	370	380	375	370	345
SUBSEQUENT DILUTION	5.4	9.0	16.1	110.2	6.7	7.8	9.4	11.5
REQUIRED DIAMETER OF ZONE OF MIXING (feet)	280	480	940	----	340	400	500	660

Table 15B
REQUIRED DIAMETER FOR ZONE OF MIXING
TN - WEAKER STRATIFICATION

	CONTINUOUS CONDITIONS				PEAK SUPERIMPOSED ON MEDIAN			
FREQUENCY (Percent of Time Less Than or Equal to)	50%	75%	90%	95%	75%	90%	95%	100%
FLOW (mgd)								
SKS	1.83	1.95	2.00	2.10	1.95	2.00	2.10	2.61
SPC	0.56	0.64	0.71	0.76	0.64	0.71	0.76	0.79
COMBINED	2.39	2.59	2.71	2.86	2.59	2.71	2.86	3.40
CONCENTRATION (mg/l)								
SKS	66.00	79.00	90.00	114.00	79.00	90.00	114.00	125.00
SPC	104.00	121.00	140.00	146.00	121.00	140.00	146.00	183.00
COMBINED	74.90	89.38	103.10	122.50	89.38	103.10	122.50	138.48
LOADING (lbs/day, calc)								
SKS	1008	1286	1502	1998	1286	1502	1998	2723
SPC	486	646	830	926	646	830	926	1206
COMBINED	1494	1932	2332	2924	1932	2332	2924	3929
LOADING (lbs/day, data)								
SKS	1020	1228	1427	1720	1228	1427	1720	1925
SPC	477	570	673	772	570	673	772	1052
COMBINED	1497	1798	2100	2492	1798	2100	2492	2977
AMBIENT CONC. (mg/l)	0.165	0.174	0.183	0.197	0.165	0.165	0.165	0.165
STANDARD (mg/l)	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
REQUIRED DILUTION								
TOTAL DILUTION	2134	3430	6053	40768	2548	2940	3494	3951
INITIAL DILUTION	660	640	630	620	640	630	620	585
SUBSEQUENT DILUTION	3.2	5.4	9.6	65.8	4.0	4.7	5.6	6.8
REQUIRED DIAMETER OF ZONE OF MIXING (feet)	160	280	520	----	200	220	280	340

Table 15C
REQUIRED DIAMETER FOR ZONE OF MIXING
TP - STRONGER STRATIFICATION

	CONTINUOUS CONDITIONS				PEAK SUPERIMPOSED ON MEDIAN			
FREQUENCY (Percent of Time Less Than or Equal to)	50%	75%	90%	95%	75%	90%	95%	100%
FLOW (mgd)								
SKS	1.83	1.95	2.00	2.10	1.95	2.00	2.10	2.61
SPC	0.56	0.64	0.71	0.76	0.64	0.71	0.76	0.79
COMBINED	2.39	2.59	2.71	2.86	2.59	2.71	2.86	3.40
CONCENTRATION (mg/l)								
SKS	8.00	11.00	14.00	16.00	11.00	14.00	16.00	20.00
SPC	34.00	38.00	42.00	43.00	38.00	42.00	43.00	48.00
COMBINED	14.09	17.67	21.34	23.17	17.67	21.34	23.17	26.51
LOADING (lbs/day, calc)								
SKS	122	179	234	280	179	234	280	436
SPC	159	203	249	273	203	249	273	316
COMBINED	281	382	483	553	382	483	553	752
LOADING (lbs/day, data)								
SKS	127	171	230	257	171	230	257	312
SPC	153	188	208	225	188	208	225	267
COMBINED	280	359	438	482	359	438	482	579
AMBIENT CONC. (mg/l)	0.021	0.024	0.026	0.027	0.021	0.021	0.021	0.021
STANDARD (mg/l)	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
REQUIRED DILUTION								
TOTAL DILUTION	1562	2940	5326	7715	1960	2367	2572	2942
INITIAL DILUTION	395	380	375	370	380	375	370	345
SUBSEQUENT DILUTION	4.0	7.7	14.2	20.9	5.2	6.3	7.0	8.5
REQUIRED DIAMETER OF ZONE OF MIXING (feet)	200	400	800	1300	260	320	360	460

Table 15D
REQUIRED DIAMETER FOR ZONE OF MIXING
TP - WEAKER STRATIFICATION

	CONTINUOUS CONDITIONS				PEAK SUPERIMPOSED ON MEDIAN			
FREQUENCY (Percent of Time Less Than or Equal to)	50%	75%	90%	95%	75%	90%	95%	100%
FLOW (mgd)								
SKS	1.83	1.95	2.00	2.10	1.95	2.00	2.10	2.61
SPC	0.56	0.64	0.71	0.76	0.64	0.71	0.76	0.79
COMBINED	2.39	2.59	2.71	2.86	2.59	2.71	2.86	3.40
CONCENTRATION (mg/l)								
SKS	8.00	11.00	14.00	16.00	11.00	14.00	16.00	20.00
SPC	34.00	38.00	42.00	43.00	38.00	42.00	43.00	48.00
COMBINED	14.09	17.67	21.34	23.17	17.67	21.34	23.17	26.51
LOADING (lbs/day, calc)								
SKS	122	179	234	280	179	234	280	436
SPC	159	203	249	273	203	249	273	316
COMBINED	281	382	483	553	382	483	553	752
LOADING (lbs/day, data)								
SKS	127	171	230	257	171	230	257	312
SPC	153	188	208	225	188	208	225	267
COMBINED	280	359	438	482	359	438	482	579
AMBIENT CONC. (mg/l)	0.021	0.024	0.026	0.027	0.021	0.021	0.021	0.021
STANDARD (mg/l)	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
REQUIRED DILUTION								
TOTAL DILUTION	1562	2940	5326	7715	1960	2367	2572	2942
INITIAL DILUTION	660	640	630	620	640	630	620	585
SUBSEQUENT DILUTION	2.4	4.6	8.5	12.4	3.1	3.8	4.1	5.0
REQUIRED DIAMETER OF ZONE OF MIXING (feet)	120	220	460	700	160	180	200	240

- Loadings are also calculated based on flows and concentrations (indicated as "calc"). The results of this calculation are loadings higher than observed indicating a weak, and possibly negative, correlation between flow and concentration. The previously tabulated loadings (indicated as "data") are used in the following calculations of the zone of mixing size. This approach corresponds to an assumption of a strong positive correlation between flow rate and concentration which is an extremely conservative (worst case) approach.

- Ambient concentrations are based on the predictions of the wastefield transport model for the area adjacent to (but not including) the cells representing the immediate point source (Table 13).

- The required dilution is calculated based on effluent, ambient, and the desired final (water quality standard) concentrations using the same relationship given above for zone of mixing based on initial dilution.

- Initial dilutions correspond to flows as given in Table 12.

- Required distances for the mixing zone are based on the required subsequent dilution to meet the water quality standard and the relationship between distance and subsequent dilution. Subsequent dilution as a function of distance is in the output from CDIFF given in Appendix C.

During times of stronger density gradients a zone of mixing allowing a 1300 foot travel distance for the plume would provide for the worst case condition and allow for future expansion. Mean loadings could increase by about 70 percent and still be accommodated by this zone of mixing. During times of stronger density gradients the plume would remain trapped well below the surface (see Table 12 and Appendix A). Even if the plume moved toward shore it would remain submerged and not impact the coral reef.

During times of weaker density gradients the travel distance of the plume is much less than for stronger gradient conditions. This is because the initial dilution will be higher. Based on the analysis summarized in Tables 15B and 15D it appears that during times of plume surfacing the water quality standards will be met before the plume can reach the reef area.

RESULTS OF ZONE OF MIXING ANALYSIS

A conservative estimate of zone of mixing size, based on the above models and analyses, is as follows:

- For present loading levels, and for average long-term conditions, a zone of mixing of a size corresponding to two model cells appears reasonable. However, a larger size is prudent to account for known variability and projected future expansion.

- For maximum loading values, a zone of mixing of 1,300 feet in radius (centered on the outfall diffuser) appears sufficient and provides a reasonable factor of safety and allows for future increases in median loading values.

The zone of mixing is defined above such that at any given time the concentration within the zone would be above the water quality standard at the boundary of the zone over less than 1/4 of the area of the zone. Within most of such a designated zone of mixing, at any given time, the water quality standards would be met. Thus the actual size, at any time, of the area where water quality standards would not be met (an "effective" zone of mixing) is very small and would involve a fraction of one percent of the volume of the harbor. However, because the currents are always changing direction and speed, this "effective" zone of mixing is constantly moving within the borders of the overall zone of mixing. The developments presented above, on which the size of the zone of mixing was based, were constructed to be a worst case scenario. Conservative assumptions were used throughout the application of models, analysis, and data interpretation.

APPLICATION FOR ZONE OF MIXING

for

JOINT CANNERY OUTFALL
PAGO PAGO HARBOR, AMERICAN SAMOA

by

StarKist Samoa, Inc.
and
Samoa Packing Company, Inc.

July 17, 1991

1. DESCRIPTION OF PROPOSED ZONE OF MIXING

StarKist Samoa and Samoa Packing Company discharge treated wastewater from tuna cannery operations into the inner part of Pago Pago Harbor adjacent to the cannery operations. The canneries are proposing to construct a single, jointly operated, outfall extending into the outer portion of the harbor. This will provide significant improvements to the water quality of the harbor. However, a mixing zone will be required since water quality standards can not be met at the point of discharge (POD). A short project description is provided as Attachment 1 to this application.

1.1 Location of the Requested Zone of Mixing

The requested zone of mixing is located offshore of the eastern shoreline of the harbor between Anasosopo Point and Ava Point. ***The center of the diffuser (center of the zone of mixing) is approximately at Northing 305,100 and Easting 263,700 as shown in Figure 1.*** This location may change slightly during final design and construction. However, the center of the mixing zone will be within the limits for potential diffuser locations shown on Figure 1.

The location of the requested zone of mixing was determined based on a feasibility study conducted by CH2M HILL,

> *"Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives". CH2M Hill, March 1991. Final Report for StarKist Samoa, Inc.*

referred to as the Feasibility Study in discussions below. The analyses done during the Feasibility Study indicated a range of potential diffuser locations that would result in compliance with water quality standards at anticipated discharge conditions and meet other criteria as discussed below. The location proposed as shown on Figure 1 near the south end of the area of potential locations was selected based on the following factors:

- **Water Quality Standards for Pago Pago Harbor:** the allowable loading of total nitrogen (TN) and total phosphorus (TP) was predicted for locations in the harbor between the closed end (head) and open end (mouth) of the harbor. The allowable loading was considered the loading that would result in compliance with 1989 Revision of the American Samoa Water Quality Standards (ASWQS) throughout the harbor (except within the zone of mixing). As the effluent discharge location is moved from the head of the harbor toward the mouth of the harbor the allowable loadings become higher. However, a mixing zone will be required regardless of the loading or location.

- **Water Quality Standards for Open Coastal Waters:** the standards for open coastal waters are more restrictive (lower TN and TP concentrations) than for within Pago Pago Harbor. In addition the ASWQS prohibit the discharge of industrial waste into open coastal waters. The open coastal standards therefore limit the potential location of cannery effluent discharge. The discharge location must be far enough from the mouth of the harbor to allow sufficient mixing to occur to keep the mixing zone within the harbor. True ?

- **Joint Cannery Loadings:** A waste load allocation study has been done for the American Samoa Government:

  > *A Waste Load Allocation Study for Pago Pago Harbor, American Samoa. Hydro Resources International, 1989. Report for American Samoa Environmental protection Agency.*

  This study indicated that the total allowable TN and TP loadings (total maximum daily loadings, TMDLs) depended on location of the discharge point. Wasteload allocations (WLAs) for the individual canneries were also discussed in the referenced report. For the purpose of locating a discharge point during the Feasibility Study a total anticipated maximum future loading was used based on projections and estimates of each cannery. These estimates are discussed in a Technical Memorandum presenting the details of the mixing zone determination and geometry provided as Attachment 2 to this application (referred to as the Mixing Zone TM in discussions below).

- **Cost of Construction:** The length of the pipeline depends on the location required for the assumed loading. As described in the Feasibility Study the cost of the pipeline increases with length. However, the cost per unit length is not constant and varies with total length, flow rate, pipe material and other factors.

A careful consideration of each of these factors using available data, new data collected specifically for the purpose, models and engineering analysis was made to select the location of the discharge and mixing zone. The background and preliminary findings are presented in the Feasibility Study; the methods used to arrive at the final determination of the mixing zone characteristics are presented in the Mixing Zone TM.

1.2 Dimensions of the Requested Zone of Mixing

The analysis of mixing zone size was based on worst case conditions as described in the attached Mixing Zone TM which describes technical details of initial dilution calculations, subsequent and farfield dilutions, and wastefield transport throughout the harbor. ***This dimension requested is bounded by a circle centered on the midpoint of the diffuser 1300 feet in radius or by the 30 foot contour whichever is closest to the center of the diffuser.*** A graphical representation of the requested mixing zone is presented on Figure 1.

The determination of the mixing zone size considered the following factors:

- Initial dilution under expected extremes of density gradients and current speeds.
- Trapping levels under expected extremes of density gradients and current speeds.
- Subsequent (secondary) dilution under expected extremes of dilution, trapping level, and current speeds.
- Constituent concentration (background) in the receiving water under the worst case scenario of continuous discharge at the maximum anticipated effluent loading rates.

Based on the points listed above, the requested mixing zone size is conservative and designed to accommodate low probability, worst case conditions. At any given time only about 25 percent of the mixing zone area will actually be utilized (have TN and TP concentrations exceeding ASWQS). As wind, tidal, density, and other physical factors vary the spatial portion of the mixing zone being utilized will change. An even smaller percentage of the total volume of the mixing zone will be utilized at any given time.

The size of the mixing zone is described as a water surface area and the volume of water below that area. The reason it is not completely symmetrical is accounted for by the difference in trapping and non-trapping conditions. When there is a density gradient present the plume will be trapped well below the 30 foot contour and cannot spread past the solid boundary on the shoreward side of the requested mixing zone. Since the plume will be trapped below the surface, the reef area will not be impacted by the mixing zone. When the density gradient is not present or extremely weak, the plume will surface but the initial dilution will be much higher than for the case of trapping. Since the initial dilution will be higher the distance required for mixing to ASWQS will be smaller and the reef area will not be impacted by the mixing zone. - as much, but it will be impacted!

1.3 Historical and Present Water Quality Conditions

Historical water quality conditions are described in a number of references and summarized in the Use Attainability and Site Specific Criteria Analysis done for the canneries:

> *"Use Attainability and Site-Specific Criteria Analysis, Pago Pago Harbor, American Samoa". CH2M HILL, 1991. Final report for StarKist Samoa and Samoa Packing Company, March 15, 1991.*

Table 1 is from the report referenced above and summarizes the historical water quality for the various portions of Pago Pago Harbor as described in that report. Figure 2 shows the water quality sampling stations referred to in Table 1.

The initiation of high strength waste segregation and disposal at sea has significantly lowered the nutrient concentrations in the harbor. This decrease is summarized in Table 2 from data collected by ASEPA for August through December 1990 and by CH2M HILL in November 1990.

1.4 Proposed Alternate Water Quality Standards within Zone of Mixing

Applicant proposed water quality standards within the zone of mixing are described below in terms of water quality parameters at the end of the pipe (EOP), the edge of the zone of initial dilution (ZID) and at the edge of the zone of mixing. The applicant proposed standards are based on existing NPDES permit requirements and the ASWQS (1989 Revision). ***The proposed water quality standards are given in Table 3. The term "ambient" as used in Table 3 refers to the prevailing status of water quality in the harbor. This is interpreted to mean that the cannery discharges will not result in a violation of the water quality standards for the harbor at the edge of the zone of mixing. In addition the cannery discharges will not increase the levels (decrease light penetration) above harbor background (at the edge of the zone of mixing) if harbor water quality standards are not being met as a result of other factors.*** Any standards not specifically addressed in this table are proposed to remain the same within the zone of mixing as currently described for Pago Pago Harbor in the ASWQS.

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1.5 Supplementary Information

The American Samoa Environmental Quality Commission (EQC) has been supplied with a copy of the Feasibility Study and the Use Attainability Study. A short project description and Mixing Zone TM are attached to this application. It is understood that the EQC has copies of the other documents referenced in this application. ***Any additional or supplementary information requested by the EQC will, if possible, be supplied in a timely manner by StarKist Samoa, Samoa Packing Company, or by their consultants CH2M HILL and Makai Ocean Engineering, as directed.***

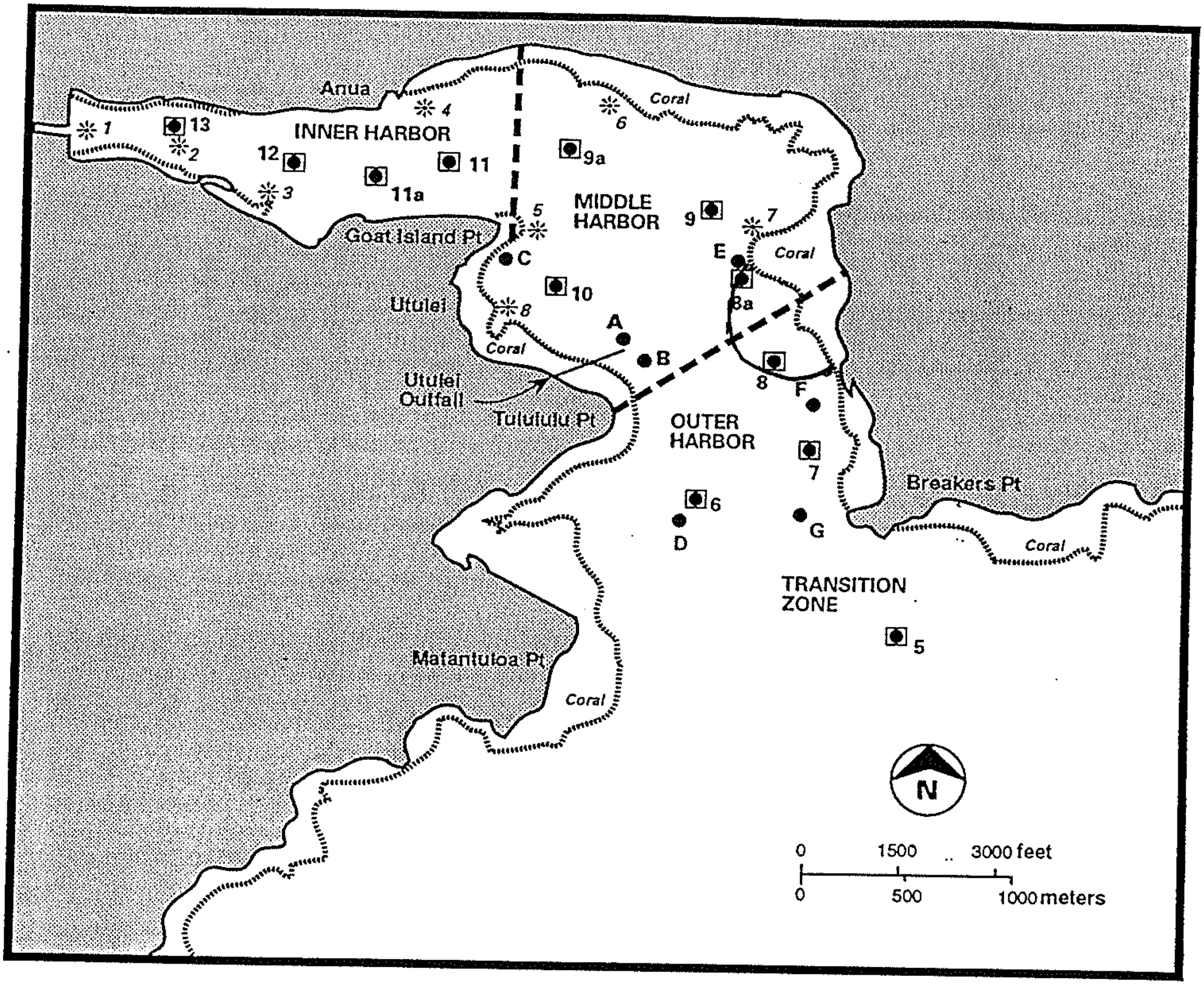
2. CONSISTENCY WITH AMERICAN SAMOA ZONE OF MIXING POLICY

The cannery operations at Pago Pago result in an unavoidable necessity for the discharge of treated wastewater into the adjacent marine waters. The technically and economically

Table 1
SUMMARY OF HISTORICAL WATER QUALITY CONDITIONS

Station	Total Nitrogen (mg/L) Mean	G. Mean	Median	No. of Values	% > WQC *	Total Phosphorus (mg/L) Mean	G. Mean	Median	No. of Values	% > WQC *	Chlorophyll a (ug/L) Mean	G. Mean	Median	No. of Values	% > WQC *	Turbidity (NTU) Mean	G. Mean	Median	No. of Values	% > WQC *
Inner Harbor																				
11	0.507	0.386	0.430	89	75.3%	0.050	0.039	0.039	91	59.3%	8.4	3.2	4.2	69	71.0%	2.16	1.398	1.40	64	82.8%
12	0.532	0.423	0.493	89	79.8%	0.063	0.052	0.061	92	75.0%	12.9	4.0	5.8	68	72.1%	2.50	1.793	1.50	63	88.9%
13	0.797	0.547	0.570	90	91.1%	0.135	0.077	0.075	92	96.7%	23.1	10.7	12.3	69	94.2%	3.40	2.484	2.40	64	100.0%
11A	0.632	0.457	0.535	78	80.8%	0.072	0.050	0.063	78	66.7%	11.0	4.4	8.7	61	78.7%	2.72	1.712	1.60	49	83.7%
All IH	0.617	0.449	0.502	346	81.8%	0.081	0.053	0.058	353	74.8%	13.9	5.0	7.6	267	79.0%	2.70	1.813	1.60	240	89.2%
Middle Harbor																				
9	0.338	0.258	0.247	90	58.8%	0.034	0.027	0.027	92	41.3%	5.5	2.0	2.0	70	65.7%	1.67	1.26	1.30	63	84.1%
9A	0.376	0.287	0.295	76	63.2%	0.042	0.033	0.032	76	52.6%	6.8	2.7	3.0	60	66.7%	1.89	1.25	1.20	50	76.0%
C	0.324	0.264	0.215	30	53.3%	0.028	0.025	0.023	30	30.0%	5.4	2.3	1.4	24	75.0%	0.75	0.69	0.50 ok	21	42.9%
10	0.262	0.217	0.220	90	55.6%	0.027	0.022	0.024	92	26.1%	3.2	1.4	1.4	70	58.6%	1.96	1.30	1.10	63	79.4%
E	0.295	0.263	0.220	30	70.0%	0.027	0.025	0.025	30	26.7%	5.1	2.3	1.6	24	75.0%	0.62	0.60	0.60	21	14.3%
8A	0.276	0.226	0.220	78	55.1%	0.027	0.023	0.023	78	34.6%	4.6	1.8	2.2	62	61.3%	1.73	1.16	1.10	50	72.0%
A	0.305	0.234	0.195	30	46.7%	0.026	0.023	0.024	30	23.3%	3.7	1.4	0.9	24	50.0%	0.56	0.50	0.76	21	14.3%
B	0.244	0.203	0.218	27	48.1%	0.025	0.022	0.023	27	25.9%	2.2	1.2	1.2	21	57.1%	0.55	0.50	0.50	18	16.7%
All MH	0.307	0.244	0.227	451	57.2%	0.031	0.025	0.025	455	35.2%	4.8	1.9	1.7	355	63.4%	1.50	1.01	1.00	307	63.5%
Outer Harbor																				
6	0.184	0.161	0.160	62	22.6%	0.019	0.017	0.018	63	7.9%	1.1	0.6	0.5	46	28.3%	1.77	1.05	1.00	37	59.5%
7	0.244	0.195	0.173	91	42.9%	0.025	0.021	0.022	92	21.7%	3.6	1.5	1.5	69	56.5%	1.49	1.06	1.00	64	68.8%
8	0.278	0.223	0.216	88	51.1%	0.028	0.024	0.023	90	31.1%	5.3	1.6	1.5	70	61.4%	1.58	1.08	1.10	64	67.2%
D	0.245	0.205	0.175	30	43.3%	0.019	0.018	0.019	30	6.7%	2.0	1.0	1.3	24	58.3%	0.63	0.58	0.70	21	38.1%
F	0.246	0.221	0.220	27	51.9%	0.023	0.022	0.024	27	14.8%	5.2	1.7	1.4	21	66.7%	0.75	0.71	0.60	21	42.9%
G	0.248	0.205	0.180	27	37.0%	0.022	0.020	0.022	27	14.8%	8.5	2.0	1.5	21	61.9%	0.70	0.61	0.70	21	42.9%
All OH	0.242	0.199	0.177	325	41.5%	0.024	0.021	0.021	329	19.1%	4.1	1.3	1.2	251	53.1%	1.34	0.92	0.90	228	59.2%

* % > WQC = Percent of values greater than existing water quality criterion.



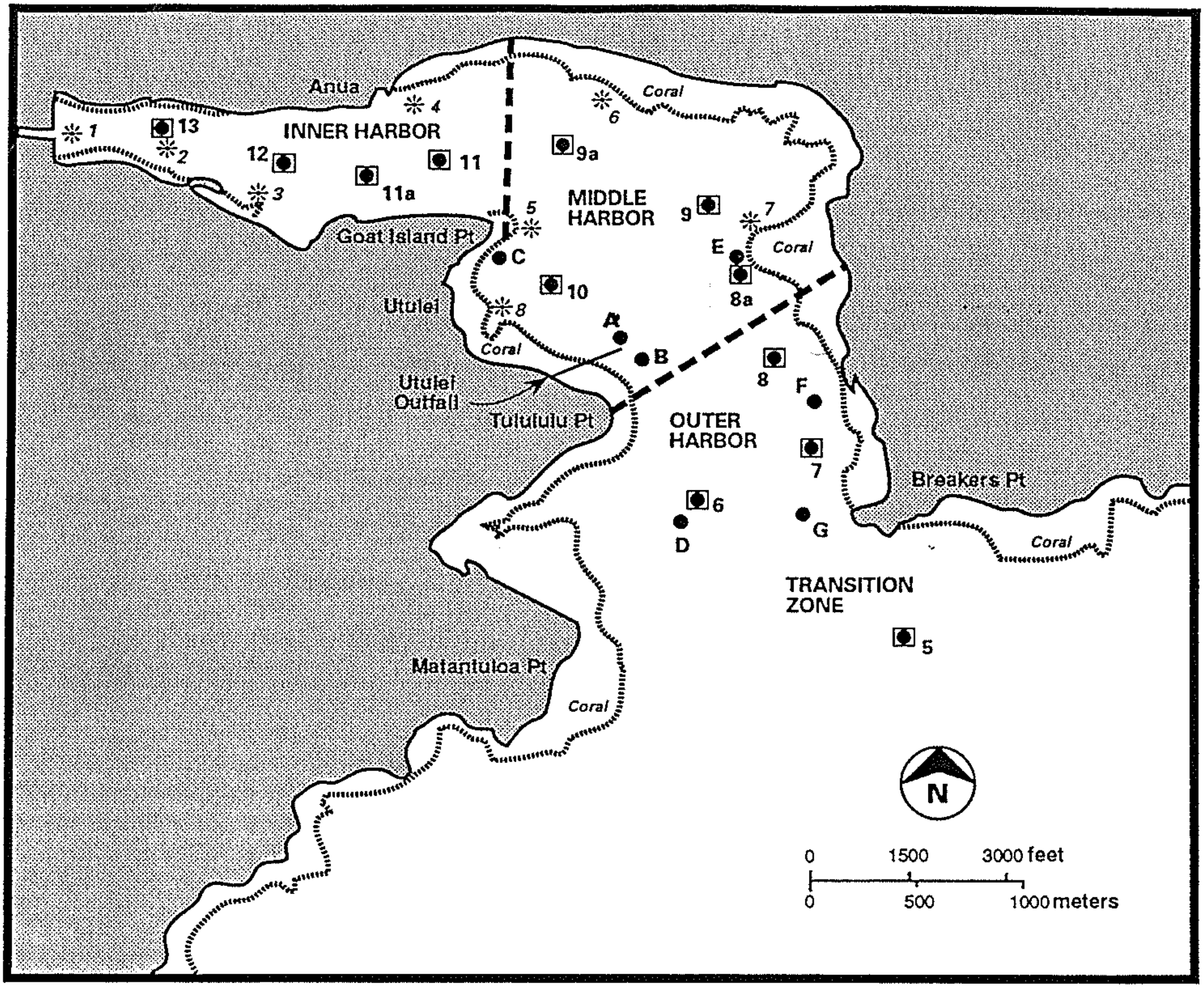
LEGEND

ASG Sampling Station

Utulei WWTP Station

CH2M HILL Field Measurement Station (1/19/91)

FIGURE 2. LOCATION OF WATER QUALITY STATIONS IN PAGO PAGO HARBOR



LEGEND

ASG Sampling Station

Utulei WWTP Station

CH2M HILL Field Measurement Station (1/19/91)

FIGURE 2
LOCATION OF WATER QUALITY STATIONS IN PAGO PAGO HARBOR

Table 2
AVERAGE TN AND TP CONCENTRATIONS
BEFORE AND AFTER HIGH STRENGTH WASTE SEGREGATION

STATION	TOTAL NITROGEN				TOTAL PHOSPHORUS			
	SURFACE		DEEP		SURFACE		DEEP	
	BEFORE HSWS	AFTER HSWS	BEFORE HSWS	AFTER HSWS	BEFORE HSWS	AFTER HSWS	BEFORE HSWS	AFTER HSWS
13	709	458	724	456	101	51	106	56
12	693	436	723	320	94	60	73	55
11	1046	270	863	270	84	36	71	32
11A	1313	384	1051	278	113	57	94	42
10	461	190	323	138	34	26	24	22
9	503	208	507	168	57	23	46	17
9A	433	224	409	160	43	28	40	19
8	383	154	280	152	34	21	29	17
8A	266	190	296	158	29	23	21	17
7	207	184	191	132	23	20	21	19
6	295	238	215	130	28	27	23	13

NOTES: Station locations are shown in Figure 3.

Before high strength waste segregation (HSWS) data are averages of measurements between July 1989 and March 1990.

After high strength waste segregation (HSWS) data are averages of measurements between August and December 1990.

Table 3
PROPOSED ALTERNATE WATER QUALITY STANDARDS
for
REQUESTED ZONE OF MIXING

STANDARD	DESCRIPTION	LOCATION WHERE STANDARD APPLIED: POD	ZID	ZOM	HARBOR
Standards for Waters Generally:					
24.0207 (a) (1)	Objectionable character	N/A (1)	Meets Existing	Meets Existing	Apply Existing
24.0207 (a) (2)	Visible Floatables	N/A (1)	Meets Existing	Meets Existing	Apply Existing
24.0207 (a) (3)	Visible turbidity	N/A (1)	Meets Existing	Meets Existing	Apply Existing
24.0207 (a) (4)	Toxic Substances	Meets Existing	Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (5)	Fecal Coliform	Meets Existing	Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (6)	Temperature	Maximum 90 degrees F	(2) Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (7)	Radioactivity	Meets Existing	Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (8)	Toxic Substances	(3) Meets Existing	(3) Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (9)	Currents and Circulation	Meets Existing	Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (10)	Sedimentation	Meets Existing	Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (11)	Salinity Distribution	N/A (2)	(2) Meets Existing	Meets Existing	Meets Existing
24.0207 (a) (12)	Residual Chlorine	Meets Existing	Meets Existing	Meets Existing	Meets Existing
Standards for Pago Pago Harbor:					
24.0207 (c) (1)	Turbidity	N/A (4)	N/A (4)	Ambient (4)	Apply Existing
24.0207 (c) (2)	Total Phosphorus	N/A (5)	150 ug/l	30 ug/l	Apply Existing
24.0207 (c) (3)	Total Nitrogen	N/A (5)	1000 ug/l	200 ug/l	Apply Existing
24.0207 (c) (4)	Chlorophyll-a	N/A (4)	N/A (4)	Ambient (4)	Apply Existing
24.0207 (c) (5)	Light Penetration	N/A (4)	N/A (4)	Ambient (4)	Apply Existing
24.0207 (c) (6)	Dissolved Oxygen	N/A (2)	(2) Meets Existing	Meets Existing	Meets Existing
24.0207 (c) (7)	pH	Meets Existing	Meets Existing	Meets Existing	Meets Existing

Will not meet 0.75 NTU

or

1.0 ug/l

or

≥ 65' 50 Tim at edge of ZOM

NOTES:
POD = Point of Discharge (at diffuser port)
ZID = Edge of Zone of Initial Dilution (equal to water depth)
ZOM = Edge of Zone of Mixing (as requested in application)
(1) End of pipe in 180 feet of water and high initial dilution in ZID.
(2) Difference at edge of ZID will be undetectable from ambient.
(3) No toxic substances above standards have been identified.
(4) Will meet ambient at edge of ZOM. Will not cause violation outside of ZOM.
(5) Standard applied to edge of ZID and ZOM.

don't say how far

feasible alternatives for wastewater treatment and disposal have been identified and are being presently implemented or are proposed for implementation. Present procedures include primary treatment by means of dissolved air flotation (DAF) with chemical precipitation and high strength waste segregation. DAF sludge and high strength wastes are transported to sea and dumped at a United States Environmental Protection Agency (USEPA) permitted site. Studies have indicated that overall water quality of Pago Pago Harbor can be further improved by the proposed relocation of the cannery wastewater discharge closer to the seaward end of the harbor.

The procedures described above comprise the technically and economically feasible suite of activities to reduce the impacts of wastewater on the water quality of Pago Pago Harbor. However, it is not feasible to achieve an effluent quality that meets ASWQS at the POD. This application requests the American Samoa Environmental Quality Commission (EQC) to permit a "zone of mixing", based on Section 24.0208 of the 1989 Revised ASWQS, within which alternate water quality standards will apply.

The principal constituents of concern are total nitrogen (TN) and total phosphorus (TP). The zone of mixing required for TN and TP will be sufficient to accommodate all other constituents and variables for which water quality standards are described for Pago Pago Harbor. The analyses refered to in this application indicate that all applicable water quality standards will be met at the boundary of the zone of mixing.

Based on the studies referenced in this application addressing alternative treatment and disposal alternatives, it is concluded that the creation of a zone of mixing is the only means of achieving compliance with ASWQS for the cannery wastewater discharge. All other practicable means of waste treatment and disposal have been implemented and are in place. The smallest possible zone of mixing can be achieved by continuing the presently implemented waste treatment and disposal methods and construction of a new outfall with a multiport diffuser discharging approximately 7000 feet seaward (along the centerline) of the present outfall termination.

3. CONSISTENCY WITH AMERICAN SAMOA ZONE OF MIXING CRITERIA

The criteria that must be met for EQC to grant a zone of mixing have been met as demonstrated by: material presented in this application, supporting material submitted with this application, or material included with the application by means of reference and citation. The satisfaction of these criteria is described below. All material included by reference and citation is readily available. Any material included in this application by reference and citation will be supplied to EQC on request.

3.1 Public Interest

The operation of the canneries and the improvement of water quality in Pago Pago Harbor are both clearly in the public interest. The canneries provide a significant portion of the economic base of American Samoa and account for nearly 90 percent of the private sector employment as described in the Use Attainability and Site-Specific Criteria Analysis. The improvement of the water quality of the harbor is important for enhancing and encouraging the tourism segment of the local economy. Improved water quality in the harbor also enhances the quality of life the citizens of American Samoa and the ecological health of the harbor.

The discharge of wastewater is necessary for the continued operation of the canneries. It is not feasible for the cannery discharge to meet ASWQS at the point of discharge (POD). In order for the canneries to continue operations a zone of mixing is required. Granting a zone of mixing for a relocated outfall will allow continued operation of the canneries as well as provide a significant improvement to the present water quality ~~standards.~~

3.2 Human Health and Safety

un-ionized NH_3?

The existing discharge contains no toxic or hazardous constituents and does not pose a direct or substantial threat to human health and safety. The primary constituents of concern are nutrients as characterized by TN and TP. These nutrients, at elevated levels, can potentially degrade the ecology of the harbor, but do not pose a threat to human inhabitants on the shore. The granting of a zone of mixing, in conjunction with the relocation of the outfall and addition of a diffuser, will result in more dilute effluent at the zone of initial dilution (ZID) and lower concentrations of nutrients throughout the harbor. No increased threat to human health or safety will result.

3.3 Impacts of Compliance at POD

Compliance with the water quality standards at the point of discharge would require that effluent concentrations be reduced by a factor of over 1000. This is not economically or technically feasible. Conformance to the standards at the POD would force the canneries to cease operations or modify operations in a manner that would significantly reduce their economic benefit to American Samoa. Extension of the outfall and permitting of a mixing zone will improve water quality and allow continued operation of the canneries.

3.4 Disruption of Marine Ecology

The relocation of the point of discharge from the present inner harbor location to the outer harbor area will result in an overall reduction of effluent constituent concentrations throughout the harbor. The use of a multiport diffuser will result in the reduction of concentrations at the edge of the ZID compared to present conditions. The location of the diffuser in deeper water will result in the effluent plume being trapped well below the surface much of the time. All of these factors will enhance the environmental conditions in Pago Pago Harbor. Nutrient levels will be lower. The contribution of cannery discharges to turbidity levels, particularly in the upper layers of the water column, will be lower. The overall effect will be an improvement in environmental conditions compared to the present conditions. The marine ecological system throughout the harbor will not be disrupted by the establishment of a zone of mixing as requested.

3.5.1 Location

The zone of mixing proposed does not extend within 500 feet of Goat Island Point at the surface or any depth within the water column beneath the surface area within 500 feet of Goat Island Point and would be in compliance with Section 24.0206 (c) (2) (C) of the ASWQS.

3.5.2 Constituents

The zone of mixing proposed is based on compliance with TN and TP standards. A zone of mixing applicable to those column? will be sufficient to provide for temperature as well. Other water quality standards will be met within the requested zone of mixing (e.g. pH, fecal coliform) or will be managed by reducing nutrient levels throughout the harbor (e.g. light penetration, chlorophyll-a, turbidity).

It is noted that it is difficult to relate light penetration, tubidity, or chlorophyll-a to nutrient discharges from the canneries. These parameters are affected by many other man made and natural factors. The analyses presented indicate that the relocation of the outfall, the use of a diffuser at depth, and the establishment of a mixing zone will have a beneficial impact on the levels of these parameters throughout the harbor.

3.5.3 Alternative Within-Zone Limits

This mixing zone application indicates the effluent POD concentrations and the edge of the ZID concentrations by which concentration levels can be specified for within the zone of mixing (Table 3).

3.5.4 Limits for Toxic Substances

check

Based on data submitted under the canneries toxic substance monitoring program (as an NPDES permit requirement), no toxic substance have been identified in the effluent and standards for such substances are not considered in this zone of mixing application.

3.6 Standards Within a Zone of Mixing

3.6.1 Color, Odor, and Taste

In the proposed location and at the proposed depth the effluent plume will be highly diluted and generally remain below the surface. During times of weak density gradient the plume may reach the surface but dilutions will increase substantially. These conditions will result in a situation that prevents objectionable color, odor, or taste in the water or in the biota within the mixing zone.

3.6.2 Floating Material

The effluent is presently subjected to primary treatment and high strength waste segregation. The resultant sludge and high strength wastes are barged and disposed of outside of the harbor. In addition the plume will be submerged and/or highly diluted. Therefore, the mixing zone will be substantially free of visible floating materials grease oil, scum, and foam.

3.6.3 Turbidity and Sedimentation

The conditions of the effluent plume and outfall location described above will prevent the formation of visible turbidity or materials that will settle to form objectionable deposits.

3.6.4 Toxic materials

The effluent has no identified toxic substances. The high initial dilution of the plume and its trapping well below the surface will prevent high nutrient concentrations that would produce undesired plankton blooms or other undesirable aquatic life.

3.7 Water Quality Standards outside the Zone of Mixing

3.7.1 Compliance with Protected and Prohibited Uses

The proposed discharge will not violate the standards and conditions specified for protected uses [24.0206 (c)]. Table 4 summarizes the impact of the project on protected uses and the compliance with prohibited uses. The only impacts will be temporary inconveniences to harbor traffic during construction and potential minor adjustments to anchorage practices. The overall impact of the proposed outfall relocation, diffuser configuration, and establishment of a zone of mixing will be an improvement of water quality ~~standards~~ throughout the harbor while allowing the canneries to continue operations.

3.7.2 Compliance with Water Quality Standards

The proposed zone of mixing will not result in a violation of the ASWQS Section 26.0207 provisions outside the mixing zone. The net result of the outfall relocation, the use of a multiport diffuser at depth, and the establishment of a zone of mixing will be an improvement of water quality standards throughout the harbor.

Table 4

COMPLIANCE WITH PROTECTED AND PROHIBITED USES SECTION 24.0206 (c)(2)(A) AND (B)

(A)	PROTECTED USES	IMPACT OF PROJECT
I	Recreational and subsistence fishing	Potential improvement by improved water quality
II	Boat-launching ramps and designated mooring areas	(see IX below)
III	Subsistence food gathering, e.g. shell-fish gathering	Potential improvement by improved water quality
IV	Aesthetic enjoyment	
V	Whole and limited body-contact recreation, e.g. swimming, snorkeling, scuba diving	
VI	Support and propagation of marine life	
VII	Industrial water supply	
VIII	Mari-culture development	
IX	Normal harbor activities; e.g. ship movments, docking, (un)loading, marine railways, and floating drydocks	Temporary impact during construction (no major interference). Minor changes in anchorage operations.
X	Scientific investigations	Potential improvement by improved water quality
(B)	**PROHIBITED USES**	**COMPLIANCE**
I	Dumping or discharge of solid waste	In compliance (no activity of this kind)
II	Animal pens over or adjacent to any shoreline (25.1604 ASCA)	
III	Dredging and filling activities; except as approved by EQC in accordance with the Environmental Quality Act (Title 24, ASCA)	
IV	Hazardous and radioactive waste discharges	
V	Discharge of oil sludge, oil refuse, fuel oil, or bilge water, or any other waste water from any vessel or unpermitted shoreside facility (20.1714 ASCA)	

3.8 Additional Considerations

3.8.1 Protected Uses

The establishment of a zone of mixing will not adversely impact any of the 10 protected uses for Pago Pago Harbor listed in the ASWQS. Protected uses will be maintained (Table 4). The establishment of a mixing zone as describe in this application will improve water quality conditions and therefore improve environmental conditions for most of the protected uses specified for Pago Pago Harbor.

3.8.2 Existing Conditions

The establishment of a zone of mixing will have short and long term beneficial impacts on existing conditions because of improved water quality (improved nutrient concentrations) throughout the harbor.

3.8.3 Character of the Effluent

The effluent at POD will be essentially the same as it is now. The effluent plume will be more dilute at the edge of the ZID. The effluent plume will meet water quality standards at the edge of the zone of mixing. The effluent is not toxic and its primary characteristic is high TN and TP concentrations.

3.8.4 Outfall and Diffuser Design

The outfall design parameters important to final water quality considerations are location and diffuser configuration. The location of the outfall and general configuration of the diffuser resulted from the Feasibility Study of alternative locations and configurations. A final analysis of the joint cannery outfall location and diffuser configuration is provided in the supporting technical memorandum attached to this application.

3.8.5 Other Policies, Plans, Agencies

Section 7 coordination with USFWS and NMFS has been initiated. Section 106 coordination with the Territorial Archaeologist has been initiated. The American Samoa Coastal Management Program, the American Samoa Environmental Protection Agency, the Environmental Quality Commission, the U.S. Environmental Protection Agency, and the U.S. Corps of Engineers are being consulted and appropriate permits are being applied for. The Review Agencies of the Project Notification and Review System have provided guidance in the permitting requirements for the construction and use of the outfall and in obtaining approval for the mixing zone. No other policies, plans, or agencies have been identified with direct substantial interest in this application.

4. CONSISTENCY WITH APPLICATION PROCEDURES FOR MIXING ZONE

The ASWQS (Section 24.0208) describes the procedures required to apply for a zone of mixing. This application has complied with those requirements and recognizes the restrictions on the requested zone of mixing stated in Section 24.0208. In addition this application complies with the requirements of the Project Notification and Review System as stated in a letter dated 27 December, 1990 (Lelei Peau to David Simpson).

4.1 Required Description

Section 1 of this application contains a description of the historical and present water quality conditions. The comparison of present conditions is made by reference to the Use Attainability and Site-Specific Criteria Analysis. The proposed alternate water quality standards, including a description of the requested mixing zone, are contained in Section 1 of this application, the attached Mixing Zone Technical Memorandum, and other referenced documents.

4.2 Supporting Information

The intent of this application is to supply, directly or by reference, all information required to review and act on the request for a mixing zone. Additional data required will be provided on request.

4.3 Conditions on the Zone of Mixing

This application for a zone of mixing is made with the understanding that the requirements and time periods of Section 24.0208 (c) (3) will apply:

4.3.1 Grounds for Granting a Mixing Zone

This application for a mixing zone is based on the grounds that it is technically and economically not feasible to otherwise conform to water quality standards in Pago Pago Harbor. A thorough review of the known and available means of otherwise conforming to the water quality standards has been made as described in the Feasibility Study, the Wasteload Allocation Study, the Joint Cannery Studies, and the Wastewater Treatment Evaluation Study. The first two of these studies are referenced above. The latter are:

"Joint Study of Fish Cannery Wastewater Effluent Loading Reduction at Pago Pago Harbor, American Samoa". CH2M HILL, 1984. Draft Phase 1 Report to American Samoa Government, Ralston Purina Company, and StarKist Foods, Inc., November 1984.

"Joint Study of Fish Cannery Wastewater Effluent Loading Reduction at Pago Pago Harbor, American Samoa". CH2M HILL, 1987. Draft Phase 2 Report to American Samoa Government, Ralston Purina Company, and StarKist Foods, Inc., June 1987.

"Wastewater Treatment System Evaluation". CH2M HILL, 1991. Report to Samoa Packing Company, June 1991.

Theses studies indicate that high strength waste segregation and outfall relocation with a multiport diffuser are the most feasible and practical ways of reducing the impact of cannery discharge on water quality. High strength waste segregation has been instituted and this mixing zone application is in conjunction with the outfall relocation.

4.3.2 Period of Zone of Mixing Permit

It is understood that the permit for the zone of mixing will be concurrent with an NPDES permit and be for a period of five years, unless a longer permit is granted..

4.3.3 Sampling and Testing

It is understood that EQC will require effluent and receiving water sampling and testing and other requirements may be specified as a condition of the zone of mixing permit.

4.3.4 Renewal of the Zone of Mixing

It is understood that the zone of mixing may be renewed if all conditions of the previous zone of mixing have been met, an application for renewal is filed, and such application is made at least 120 days prior to the expiration of the current zone of mixing permit.

4.3.5 Conditions for Termination

It is understood that the zone of mixing may be terminated, after a hearing held by EQC, for the reasons and under the conditions described in ASWQS Section 24.0208 (c) (3) (E).

4.3.6 Expiration

It is understood that the zone of mixing shall terminate at the end of the period stated for the zone of mixing unless a renewal application has been made. If a renewal application is made the zone of mixing will continue until the renewal has been approved or denied.

4.3.7 Compliance with Zone of Mixing Conditions

It is understood that compliance with the zone of mixing conditions will include the condition that water quality standards in the adjacent waters will be met under the worst case receiving-water mixing and transport conditions. The zone of mixing proposed in Section 1 above was determined under worst case conditions.

4.3.8 Impacts to Coral Reef

The zone of mixing was designed to prevent impacts to the coral reef areas as described in Section 1 above, the attachments to this application, and the material referenced in this application.

4.3.9 Temporary Withdrawal

It is understood that in an emergency the zone of mixing can be temporarily withdrawn. It is requested that the procedures to be used in such an emergency be specified in the zone of mixing permit.

4.3.10 USEPA Approval

This zone of mixing application is being sent to the USEPA, Region IX, Office of Pacific Island and Native American Programs, concurrent with submission to EQC.

ATTACHMENT 1

SHORT PROJECT DESCRIPTION

A more detailed project description and be found in the
Draft Environmental Impact Assessment for Joint Cannery Outfall Project,
Pago Pago Harbor, American Samoa (CH2M HILL, August 1991)

MEMORANDUM

CH2M HILL

TO: File

COPIES: Norman Wei/Starkist Seafood Company
James Cox/Van Camp Seafood Company
Andrew Resnick/Makai Ocean Engineering
Sheila Wiegman/ASEPA

FROM: Steve Costa/CH2M HILL

DATE: July 15, 1991
(Figures 2, 3 and 4 revised 7 August 1991)

SUBJECT: Brief Description of Joint Cannery Outfall Project

PROJECT: PDX30702.PA

JOINT CANNERY OUTFALL PROJECT DESCRIPTION

The proposed joint cannery outfall replaces two existing outfalls for StarKist Samoa, Inc. and Samoa Packing Company located in Pago Pago Harbor, American Samoa (Figure 1). The joint cannery outfall diffuser will be located approximately 7,000 feet seaward from the existing outfalls. The proposed outfall pipeline is a 16-inch diameter high density polyethylene pipe that would carry wastewater from the cannery operations. The proposed pipeline route is indicated on Figure 2. A more detailed description and analysis of the pipeline route and alternatives is included in the Environmental Impact Assessment for the project. The outfall pipeline will originate on land at the same location as the existing cannery outfalls. The cannery pumping stations will be retrofitted or replaced to accommodate the longer outfall pipeline.

The proposed pipeline will be attached to an existing dock and enter the harbor at the terminus of the dock fronting the canneries (Figure 3). The pipeline will be placed on the bottom of the harbor from a barge. No trenching or burial will be done. Where the pipeline crosses the entrance to the Trading Point cove, in water depths of 40 to 65 feet, it will be covered with pre-cast concrete sections or tremie poured concrete into preset forms for protection from boat anchors.

From Trading Point seaward the pipeline will be placed approximately parallel to the coral reef in water depths between 65 and 180 feet. The pipeline will follow along the coral reef easterly between Trading Point and the Pago Pago Harbor navigation range line (Figure 2). The pipeline will then approximately follow the harbor navigation range line until reaching the diffuser area between Ava Point and Anasosopo Point.

The pipeline will terminate offshore of the coral reef in about 180 feet of water. The diffuser will be located east of the Pago Pago navigation range line to avoid interference with an anchorage designated by the harbor master. The diffuser will have 4-inch to 6-inch diameter ports, spaced between 35 to 50 feet apart. An example of the diffuser structure is shown on Figure 4. The precise number of ports will be determined in the final mixing zone analysis for the project.

The pipeline will be anchored to the bottom in some locations with an anchoring pin system secured by chains or other mechanical attachments to facilitate laying the pipe at the correct depth and angle. Along steep relief portions of the pipeline alignment anchor pins will be attached to the coral by the use of holes drilled into the coral. Epoxy will be injected into the holes to secure the anchor pin positioning. Anchoring will also be necessary at bends in the pipeline route such as in the area where the pipeline turns south near the harbor navigation range line.

The pipeline construction will require the use of about two acres of land for mobilization and staging activity. Land availability is limited along the shoreline of Pago Pago Harbor. The construction is expected to take 3 to 4 months. A construction staging area is proposed in a limited portion of Pago Pago Park near Malaeoletalu Field. The flat open area located next to Laolao Stream and Pago Pago Harbor (Figure 5) would meet mobilization and staging requirements.

Mobilization activity will involve the transport of pipe materials, collar weights, and welding equipment to the site. Truck access through the park will be required and existing roads will be used whenever possible. After completion of the mobilization activity the park grounds will be returned to original condition and re-vegetated as necessary. Minor grading may be required in preparation of the site but soil loss will not present a problem. All construction materials will be removed at the time of project completion.

During construction staging the 40-foot pipe sections would be joined into longer sections and collar weights installed. The land-side mobilization will maximize the length of the pipe sections. The long pipe sections could then be pulled into the water using a temporary ramp to protect and traverse the shoreline. The long pipe sections may be stored in the water on a temporary basis while awaiting placement. The pipe sections would be flooded for sinking and either joined up from a boat or on the bottom by divers.

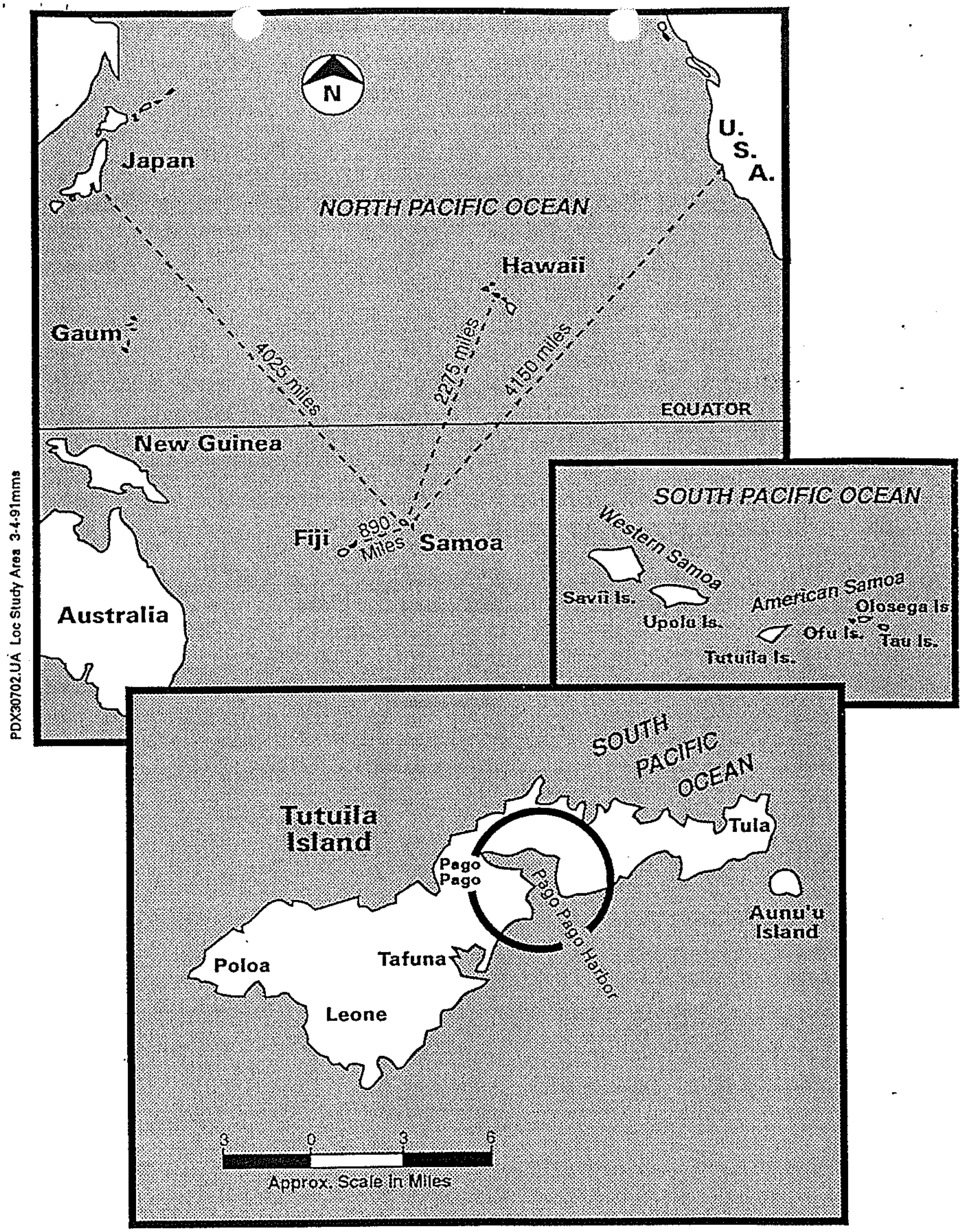


FIGURE 1
JOINT CANNERY OUTFALL
GENERAL LOCATION

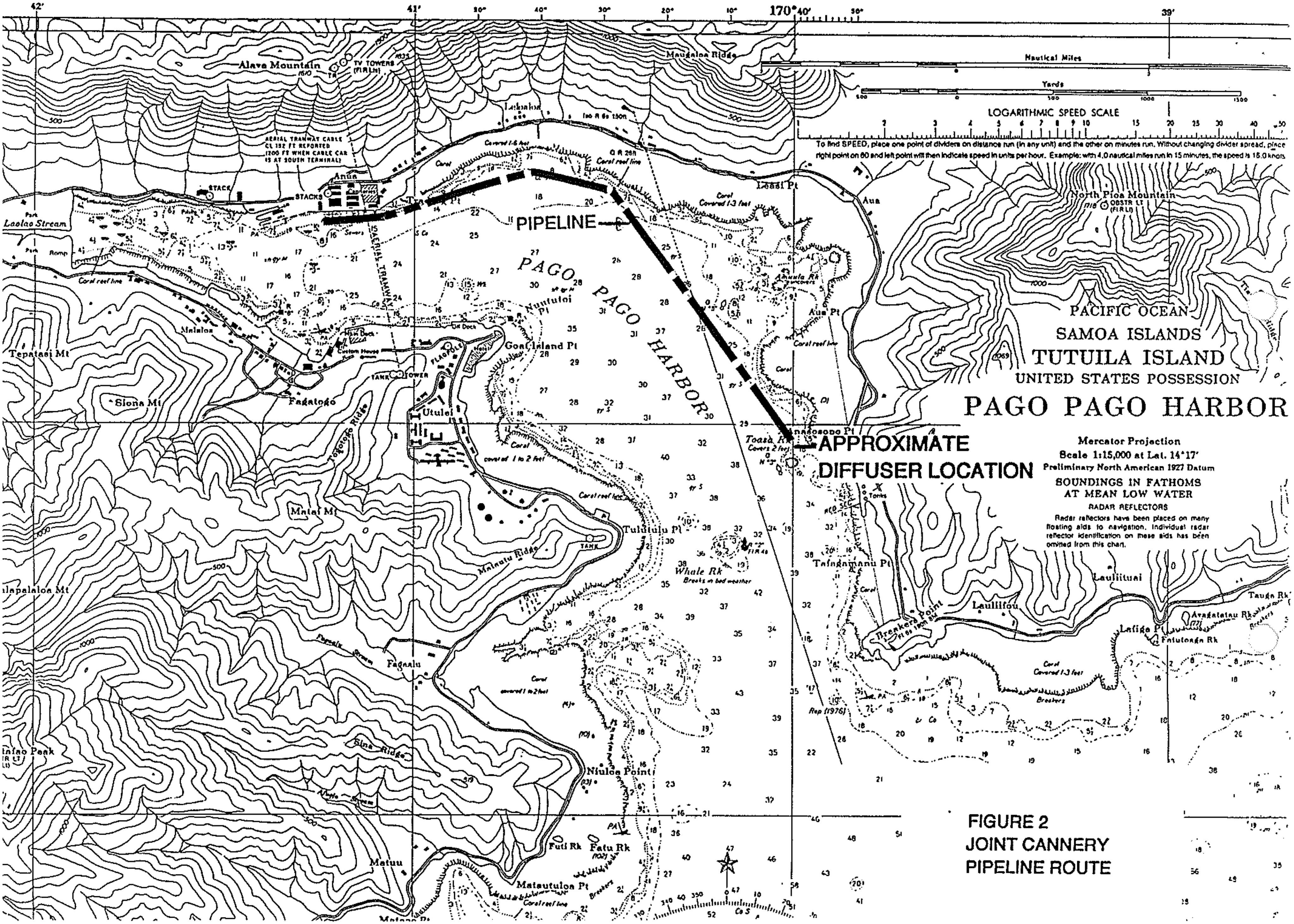


FIGURE 2
JOINT CANNERY
PIPELINE ROUTE

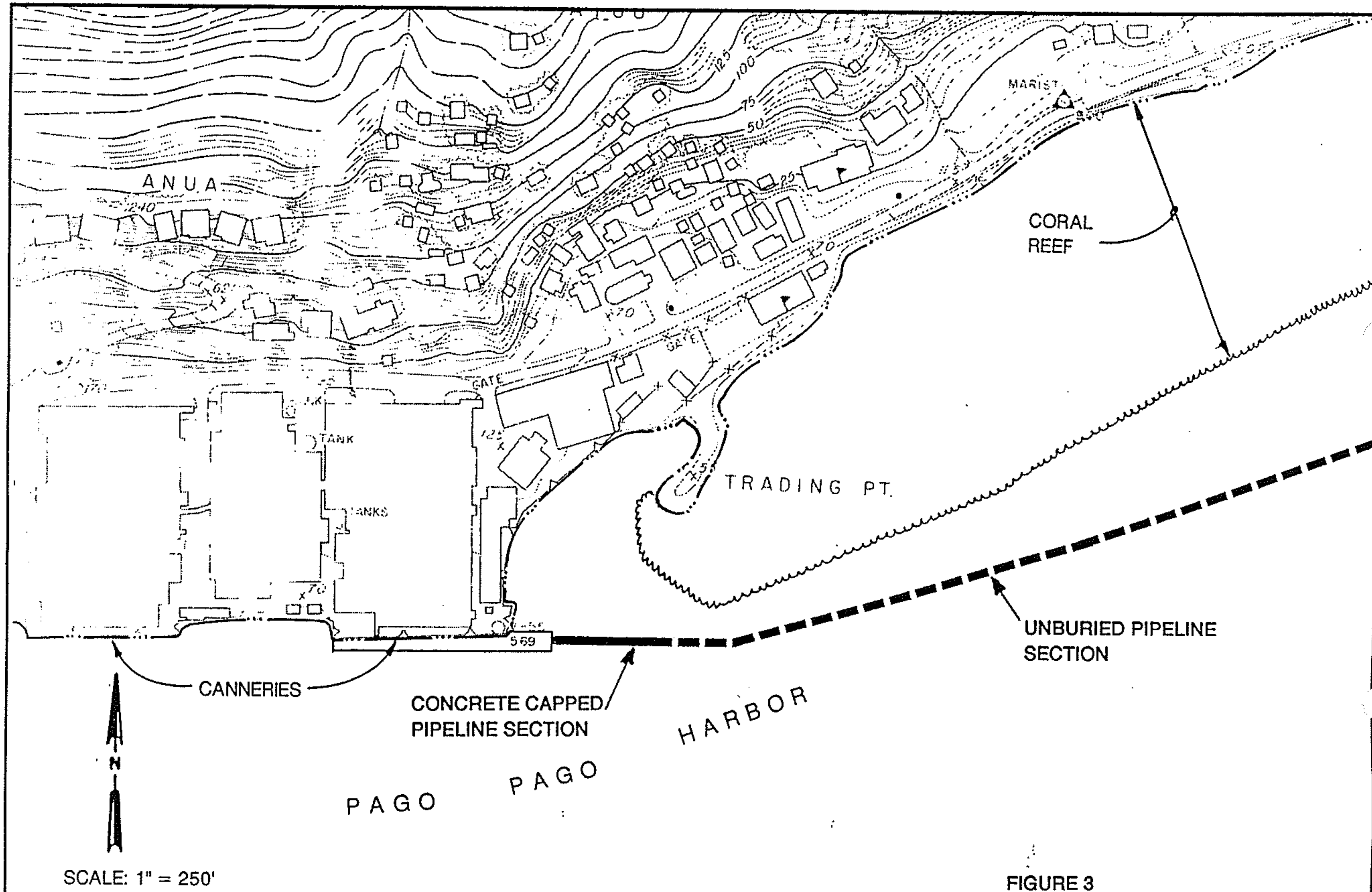


FIGURE 3
JOINT CANNERY PIPELINE ROUTE
IN VICINITY OF TRADING POINT

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CH2M HILL

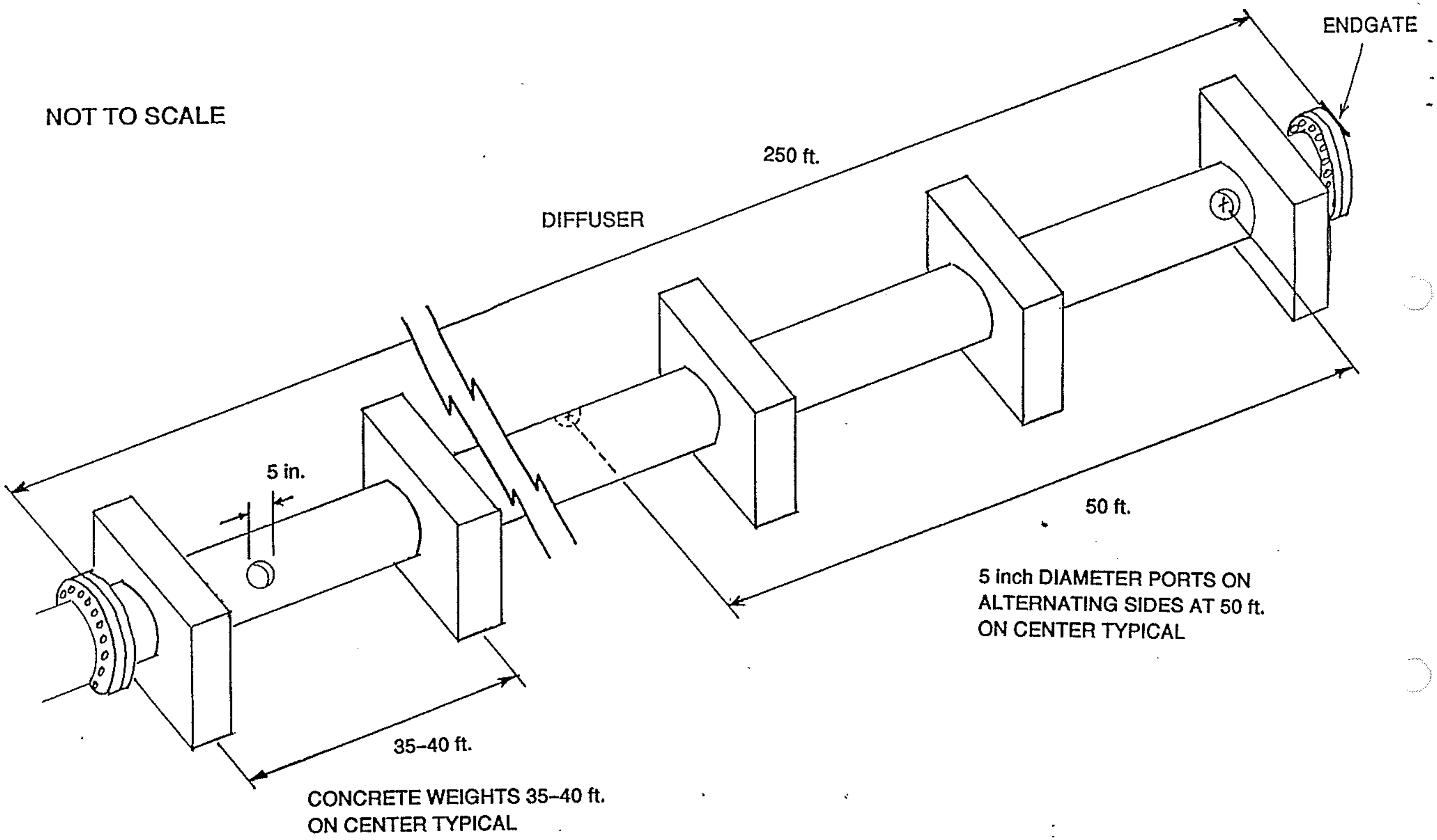


FIGURE 4
EXAMPLE OF OUTFALL DIFFUSER

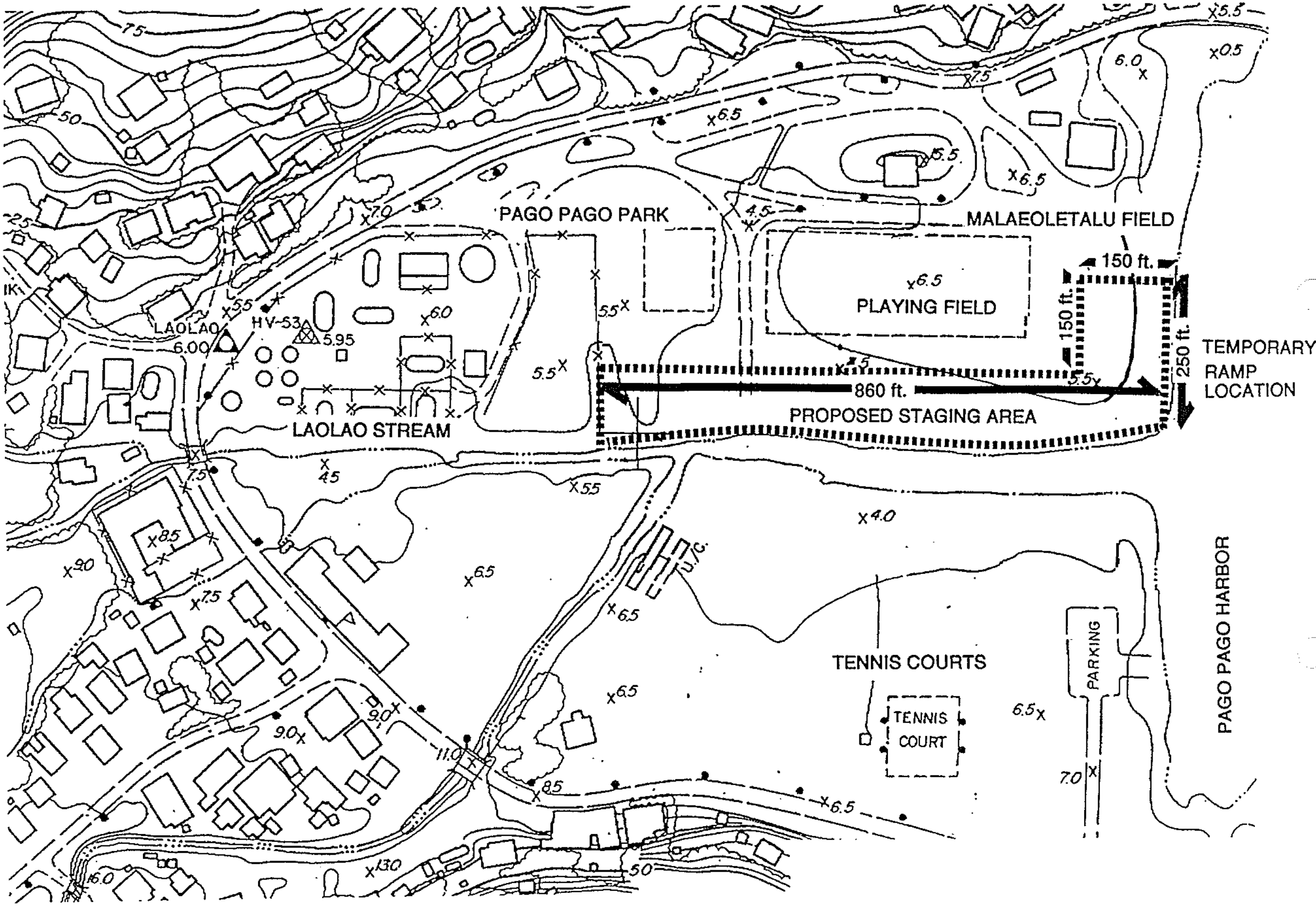


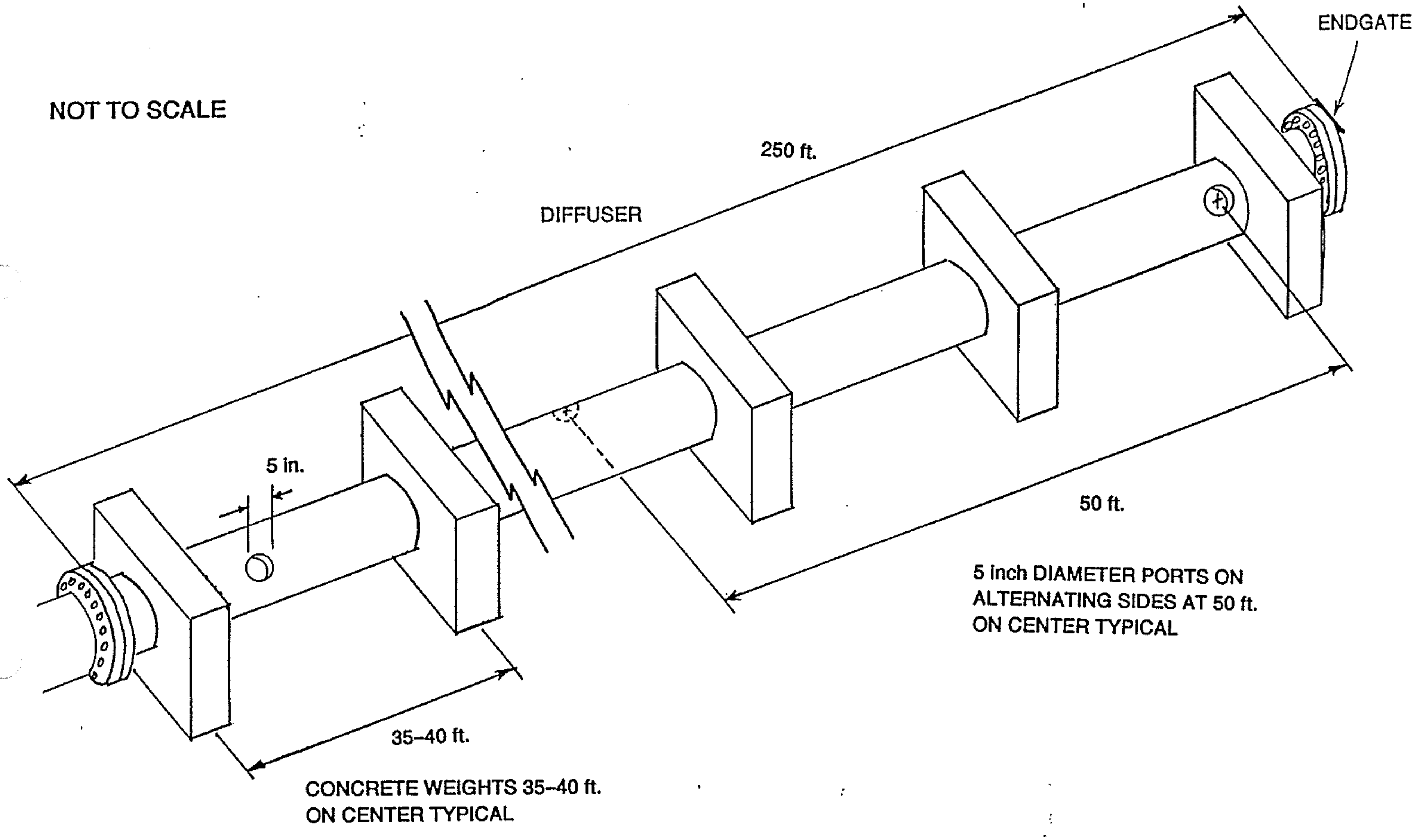
FIGURE 5
PAGO PAGO PARK CONSTRUCTION STAGING AREA

ATTACHMENT 2

TECHNICAL MEMORANDUM
SITE-SPECIFIC MIXING ZONE DETERMINATION FOR THE JOINT CANNERY OUTFALL PROJECT PAGO PAGO HARBOR, AMERICAN SAMOA

(This memorandum will be forwarded separately by 19 August 1991)

The purpose of this technical memorandum is to provide technical documentation for the zone of mixing application for the joint cannery outfall. The technical approach and preliminary analyses were done for the *Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives* (CH2M HILL 1991). This technical memorandum presents a review the methodology developed during the Feasibility Study and addresses additional information and model results that were developed for the discharge location and diffuser configuration selected during final design. **The dimensions and location of the mixing zone are substantially the same as described in the Feasibility Study report.**



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ATTACHMENT 3

LETTERS OF AUTHORIZATION OF THE APPLICANTS' AGENT

StarKist Seafood Company

180 East Ocean Boulevard
Long Beach, California 90802-4797
Telephone: 213-590-9900

An Affiliate of H.J. Heinz Company

Heinz

June 26, 1991

To whom it may concern;

On behalf of StarKist Samoa, Inc. I hereby designate and authorize CH2M HILL, and CH2M HILL's project manager STEVEN L. COSTA, to submit permit applications for the American Samoa Joint Cannery Outfall project and to furnish supplemental information in support of the application.

Sincerely,

Norman Wei
Senior Manager
Environmental Engineering
StarKist Seafood Company

VAN CAMP
SEAFOOD
COMPANY, INC.

RECEIVED
JUL - 1 1991
CH2M-HILL
SAN FRANCISCO

June 26, 1991

TO WHOM IT MAY CONCERN:

On behalf of Samoa Packing Company, I hereby designate and authorize CH2M HILL, and CH2M HILL's project manager STEVEN L. COSTA, to submit permit applications for the American Samoa Joint Cannery Outfall project and to furnish supplemental information in support of the application.

Sincerely,

James L. Cox

James L. Cox, Director
Engineering and Environmental Affairs

JLC:ms

4510 Executive Drive, Suite 300 San Diego, CA 92121-3029
Phone: (619) 558-9662 FAX: (619) 597-4282